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CONTRIBUTIONS TO THE STRATIGRAPHY AND PALAEONTOLOGY OF THE GOSHEN HOLE AREA, WYOMING

I

A DETAILED STUDY OF THE STRUCTURE AND RELATIONSHIPS OF A NEW ZALAMBDODONT INSECTIVORE FROM THE MIDDLE OLIGOCENE

By Erich M. Schlaikjer

With One Plate

CAMBRIDGE, MASS., U. S. A.
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AT HARVARD COLLEGE

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These publications are issued in numbers at irregular intervals. Each number of the Bulletin and of the Memoirs is sold separately. A price list of the publications of the Museum will be sent on application to the Director of the Museum of Comparative Zoölogy, Cambridge, Massachusetts.

Bulletin of the Museum of Comparative Zoölogy
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No. 1.— *Contributions to the Stratigraphy and Palaeontology of the Goshen Hole Area, Wyoming*

I

A Detailed Study of the Structure and Relationships of a New Zalambdodont Insectivore from the Middle Oligocene.

By Erich M. Schlaikjer

INTRODUCTION

This article is the first of a series of contributions on the stratigraphy and palaeontology of the Goshen Hole area. Goshen Hole is the name given to a region including about fifteen hundred square miles in southeastern Wyoming, which is more or less continuously surrounded by an escarpment of from four hundred to a thousand feet in height. The North Platte river bounds the area on the northeast. The escarpment begins a few miles west of the town of Torrington, and extends in semi-circular fashion around to the west, southwest, and south where it is interrupted at Bear Creek Mountain, thirty-five miles south of Torrington. To the southeast is Sixty-Six Mountain, and the eastern boundary is defined by two rather distantly separated prominences known as Eagle Nest and Table Mountain, which are situated along the Nebraska-Wyoming state line. For the past three summers the author has been in charge of fossil-collecting expeditions sent into this area by the Museum of Comparative Zoölogy at Harvard College. During this time he has made a detailed study of the stratigraphy of the region and has prepared a geological map. The area presents splendid and abundantly fossiliferous outcrops of the Lance, Chadron and Brule formations and a lower Miocene formation. A new pre-Chadron post-Uinta formation is also present. Because of the large number of new fossil forms that have been discovered, and because of the several stratigraphic problems that have arisen, it is deemed advisable to publish a series of contributions, so that this information can be put into print prior to the preparation of a monograph on the entire area.

Following this first contribution will appear a series of five or six papers dealing with the several formations and their faunas, and a final paper containing a summary of the problems of the whole area, emphasizing especially geological history and correlation of the formations present with those of other areas.

By way of acknowledgment I wish to express my deep gratitude to Dr. Thomas Barbour of the Museum of Comparative Zoölogy, who has made it possible for me to carry on this research both in the field and in the laboratory. I owe my thanks to President Henry Fairfield

Osborn and to Curators Walter Granger, George Gaylord Simpson, Barnum Brown, and Charles Craig Mook of the American Museum of Natural History for the kindness and coöperation they have shown in placing at my disposal for study the very excellent vertebrate fossils in that museum. I am indeed profoundly grateful to Professor William K. Gregory, under whose inspiring guidance it has been a privilege to carry on this research.

This article is confined to a detailed study of a new Zalambdodont insectivore from the Brule formation. The specimen is a beautifully preserved skull and jaws, and was found approximately two miles south and eight and one-half miles west of Torrington in the S. E. ¼. Sec. 19. T24n. R62 west of the sixth principal meridian. In stratigraphic position, the specimen was collected approximately sixty feet above the Chadron formation and two hundred and eighty feet below the highest outcrop of Brule in this locality (see Fig. 1).

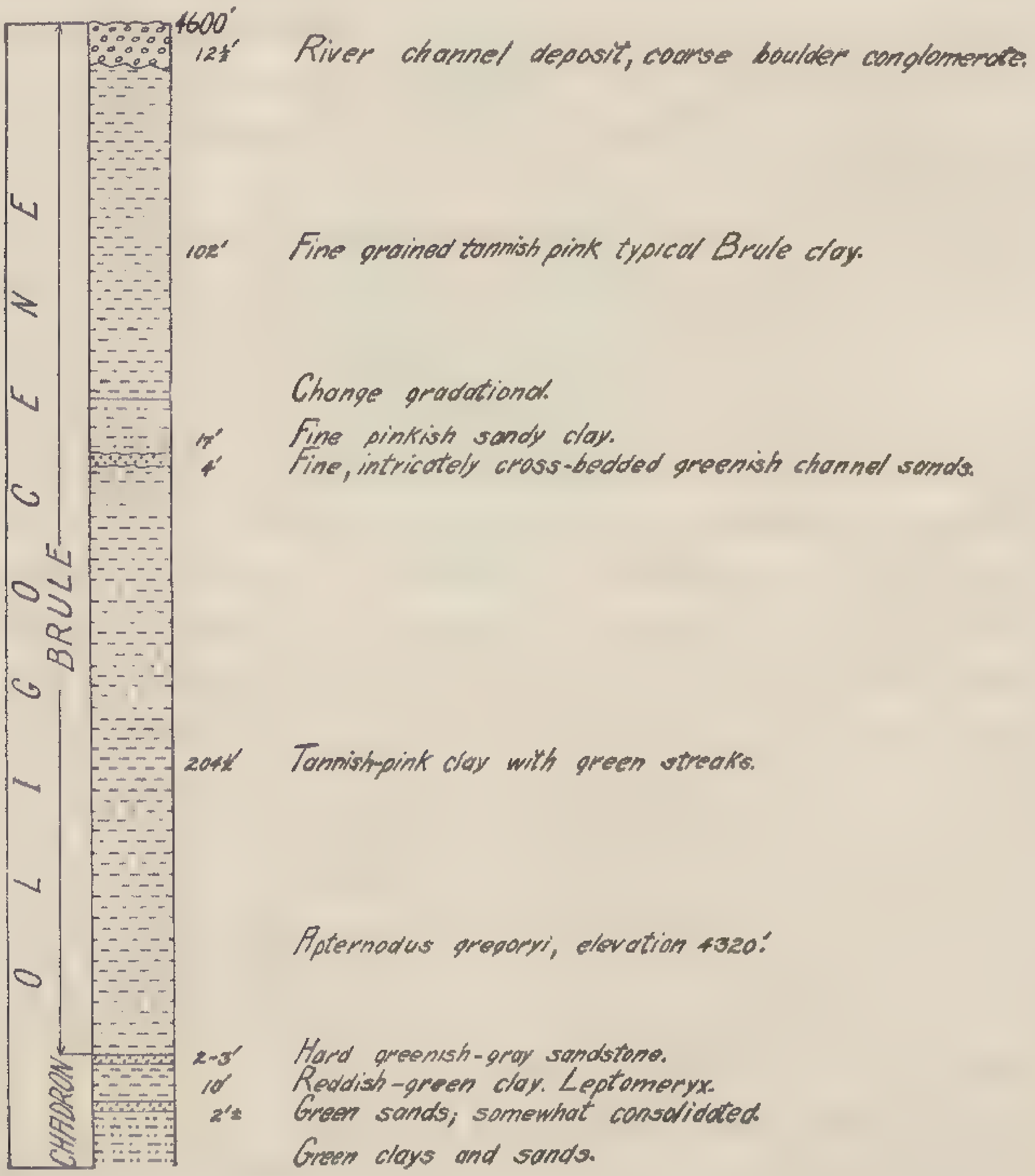
4600'
12½'
River channel deposit, coarse boulder conglomerate.
102'
Fine grained tannish pink typical Brule clay.
Change gradational.
17'
Fine pinkish sandy clay.
4'
Fine, intricately cross-bedded greenish channel sands.
204½'
Tannish-pink clay with green streaks.
Apternodus gregoryi, elevation 4320'.
2-3'
Hard greenish-gray sandstone.
10'
Reddish-green clay. Leptomeryx.
2½'
Green sands; somewhat consolidated.
Green clays and sands.
O L I G O C E N E
BRULE
CHADRON

FIG. 1. Geological section of a canyon in S. E. ¼ Sec. 19. T24n. R62w. Goshen Co., Wyoming. E. M. Schlaikjer 1932.

Inasmuch as the Brule formation is completely represented in the Goshen Hole area and is approximately four hundred feet in thickness, it is evident that the specimen comes from what may be called lower Brule, or the equivalent of what is known as the lower Oreodon zone in South Dakota and Nebraska. The matrix is of the usual very fine-grained pinkish-gray clay so characteristic of the Brule formation throughout the Great Plains area.

The fossil record of Zalambdodont insectivores is very incomplete. Only six genera and as many species have been recorded from the entire world. The new species herein described adds a seventh. The genera and species of the fossil Zalambdodonts, the geological formation from which each comes, and the geographical distribution is as follows:

DELTATHERIDIIDAE
- *Deltatheridium pretrituberculare* Gregory & Simpson. Djadokhta formation. Mongolia.
- *Deltatheroides cretacicus* Gregory & Simpson. Djadokhta formation. Mongolia.
- *Hyotheridium dobsoni* Gregory & Simpson. Djadokhta formation. Mongolia.

PALAEORYCTIDAE
- *Palaeoryctes puercensis* Matthew. Torrejon formation. New Mexico, North America.

SOLENODONTIDAE
- Subfamily SOLENODONTINAE NEW.
  - *Micropternodus borealis* Matthew. Lower Oligocene formation. Montana, North America.
- Subfamily APTERNODONTINAE
  - *Apternodus mediaevus* Matthew. Lower Oligocene formation. Montana, North America.
  - *Apternodus gregoryi* Schlaikjer. Middle Oligocene formation. Wyoming, North America.

It will be noticed at once that the three American Oligocene forms are placed in the family Solenodontidae. This problem of taxonomy will be considered later in these pages.

The drawings in this article are by Mrs. Helen Ziska, and the specimen was most skillfully prepared by Mr. Albert Thomson.

APTERNODUS GREGORYI[1] sp. nov.

Type. M. C. Z. No. 17685. Nearly complete skull and jaws. Collected by E. M. Schlaikjer, 1932.

Horizon and locality. Middle Oligocene. Lower Brule formation, Goshen County, Wyoming.

Specific Characters. This genus includes a single species, the type (described by Matthew 1903). Inasmuch as the type is only that of a partially complete posterior portion of a lower jaw with the last two molar teeth and two paratype jaw fragments, it seems most advisable to list here only those characters of *Apternodus gregoryi* which differ from those seen in *A. mediaevus*. Those differences are as follows: 1. Jaw larger and more massive. 2. Coronoid heavier, more anteroposteriorly expanded, and more external to the tooth row. 3. Angle stronger and more inflected. 4. M_{2-3} series longer. 5. M_2 shorter, wider and heavier; talonid more reduced; and paraconid more lingually situated with respect to metaconid. 6. M_3 longer and slightly higher; and talonid larger. In addition, *A. gregoryi* differs from paratype A. M. N. H. No. 9608 in having a very much heavier mandibular condyle; and from paratype A. M. N. H. No. 9607[2] in that the central cusp of P_3 is less emphasized and the posterior cingulum extends more on the external side of the tooth.

DESCRIPTION

Upper Dentition. Dental formula $^{2?-1-3-3}$. Only the roots of two incisors are present on the right side. These are not preserved on the left. There is some doubt about the number of incisor teeth, and since the anterior portion of the premaxillary is broken, it cannot be definitely determined if another tooth were present in front of the two preserved. It is probable, however, that there were only two. The roots of the two incisors are round and show that the second from the canine is the larger. There is a diastema of ca. 1 mm. between the last incisor and the canine. The canine is larger, recurved, and has two roots. The crown is ovate in outline. It is made up of a single, large, anteriorly placed cusp and a small, low, conical heel. P^2 is double rooted and has the same general form as the canine, but it is only half as large and the cusp is proportionately much lower. The tooth is separated from the canine, as well as from P^3, by a 1.5 mm. diastema. P^3–M^3 are three-rooted. P^3 is almost symmetrically triangular with a large, relatively high, centrally placed conical cusp. The anterior, posterior and internal corners are developed into cusp-like cinguli. The one at the posterior corner is more developed, higher, and more continuous with the central cone than are the others, thus foreshadowing the condition of P^4. The width of P^4 is slightly greater than its length. It is molariform, and affords an excellent example of the transition from the premolar to the molar tooth pattern. Because of the development of the cusp at the posterior angle of the tooth, P^4 has become obliquely triangular in outline. This cusp is now almost as high as the main central cusp and is in complete union with the latter. The external anterior extension of this posterior cusp is now connected with the cusp at the anterior corner of the tooth and is developed into a complete external cingulum, the central part of which is developed into a prominence which is the homologue of the parastyle of M^1. The internal angle of the tooth is lower than any other part of the crown and presents a cusp-like cingulum with a single minute conical projection. All the molars have a much greater transverse than an antero-posterior diameter. M^1 is the largest. The parastyle, metastyle and para-metacone cusp are of equal height. The cusp at the anterior angle of the tooth is not quite of the same height and is confluent with a complete, low, very small anterior cingulum. The internal angle of the tooth is rounded. It presents a prominent cingulum which is cusp-like, and shows a slight differentiation into two areas. Of these two areas, the anterior is the larger and may be called the protocone, while the posterior represents the hypocone. M^2 is smaller than M^1 and differs from the latter in the reduction of the metastyle and in that the anterior external cusp is conical, closely approximated to and almost as high as the parastyle. M^3 is expanded transversely and shortened antero-posteriorly. This is brought about by the approximation of the

---

[1] Named in honor of Professor William K. Gregory.

[2] This specimen is the front part of a left lower jaw with only one tooth preserved. In his description of *A. mediaevus* Matthew figured this specimen and considered the tooth to be P_4. I examined this specimen under the microscope and found the tooth to be P_3 and that the crown had been glued on the roots of P_4. It is now restored to the roots of P_3 on which it fits perfectly.

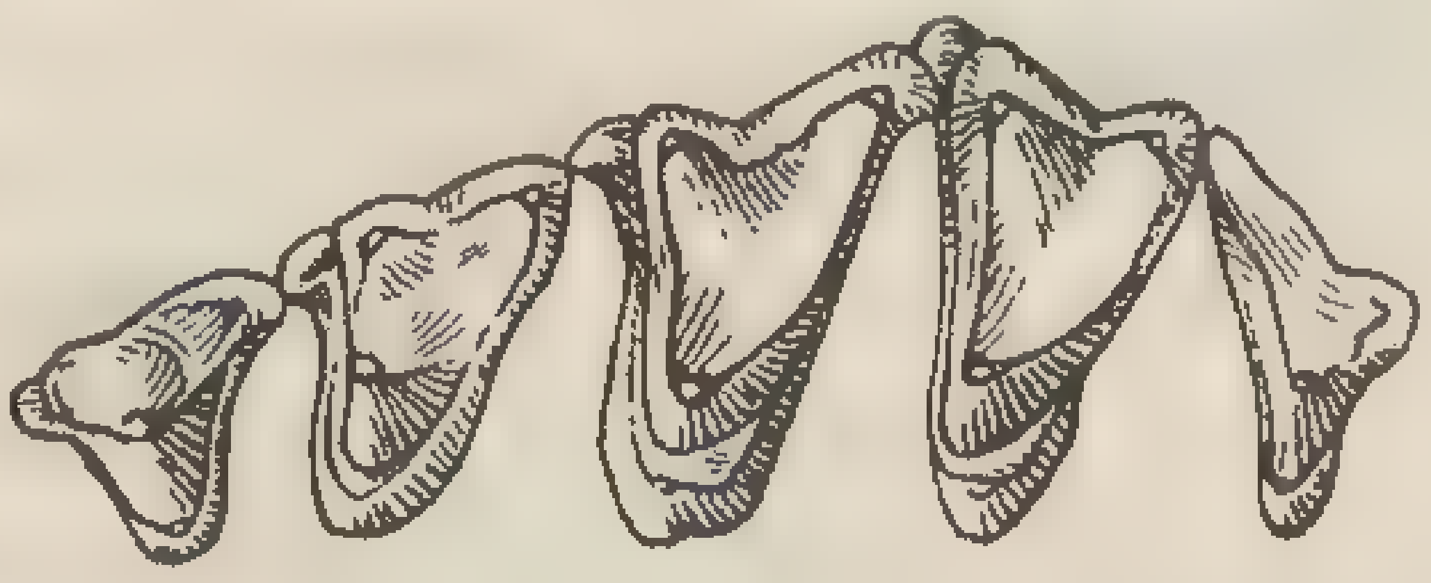

FIG. 2. *Apternodus gregoryi.* Left upper tooth series, P^3 to M^3. Five times natural size.

metastyle and para-metacone cusp; and by the development of the antero-external cusp so that it is larger and higher than the parastyle.

The Skull. The right side of the skull is perfectly preserved with the exception of the loss of the anterior tip of the premaxillary. On the left side part of the cranium is chipped away and the cast of part of the brain is exposed. The preorbital region of the skull is relatively short and uniformly cylindrical. The postorbital region is about twice the length of the preorbital. The skull is that of an adult and most of the sutures are completely fused.

The basioccipital is short and is below the level of the palate. The whole skull is bent upward from the basioccipital axis. The occipital condyles are low, broad and widely separated. The foramen magnum faces backward and downward, and there is no evidence of a notch either above or below. It is large, and oval in outline; being broader than high. The whole posterior part of the skull is greatly expanded as a result of the development of the squamosal, mastoid portion of the periotic, and exoccipital bones into a curious plate-like development at the side of the skull. This plate-like structure is rectangular in outline and is oriented obliquely to the long axis of the skull, and is considerably below the level of the sagittal crest. The dorsal edge is heavy and curves somewhat downward and outward from behind forward. The antero-dorsal corner presents a blunt zygomatic process. This slightly overhangs the large open and very transversely expanded glenoid cavity. The glenoid cavity is elevated; the dorsal edge lying on a level with the inferior part of the orbit. It faces forward and slightly outward. The post-glenoid process is small. It projects downward and forward about half way under and along the entire width of the glenoid cavity. The infero-anterior angle of this plate-like expansion is formed by the post-tympanic process. Between this and the post-glenoid process is a large and fairly deep notch for the external auditory meatus. When the jaws are articulated with the skull and are opened, the angle of the jaw fits into this notch. Opening of the mouth, therefore, must have interfered with the ability of the animal to hear. The post-tympanic process is stout, rounded and marks the most ventral point of the entire skull. Extending backward and upward from this process, the ventral portion of the skull expansion ends in the postero-inferior angle, which is stout and bluntly developed. The posterior margin of the expansion is almost vertical in position and projects only slightly behind the condyles. There seems to be a well defined suture extending dorso-ventrally just anterior to the posterior margin of this plate-like expansion. I have considered this to be the suture between the squamosal in front and the mastoid portion of the periotic behind. The sutures between the basioccipital and basisphenoid; basisphenoid and presphenoid; and presphenoid and vomers cannot be determined. The pterygoid plates are low. The suture between the basioccipital and

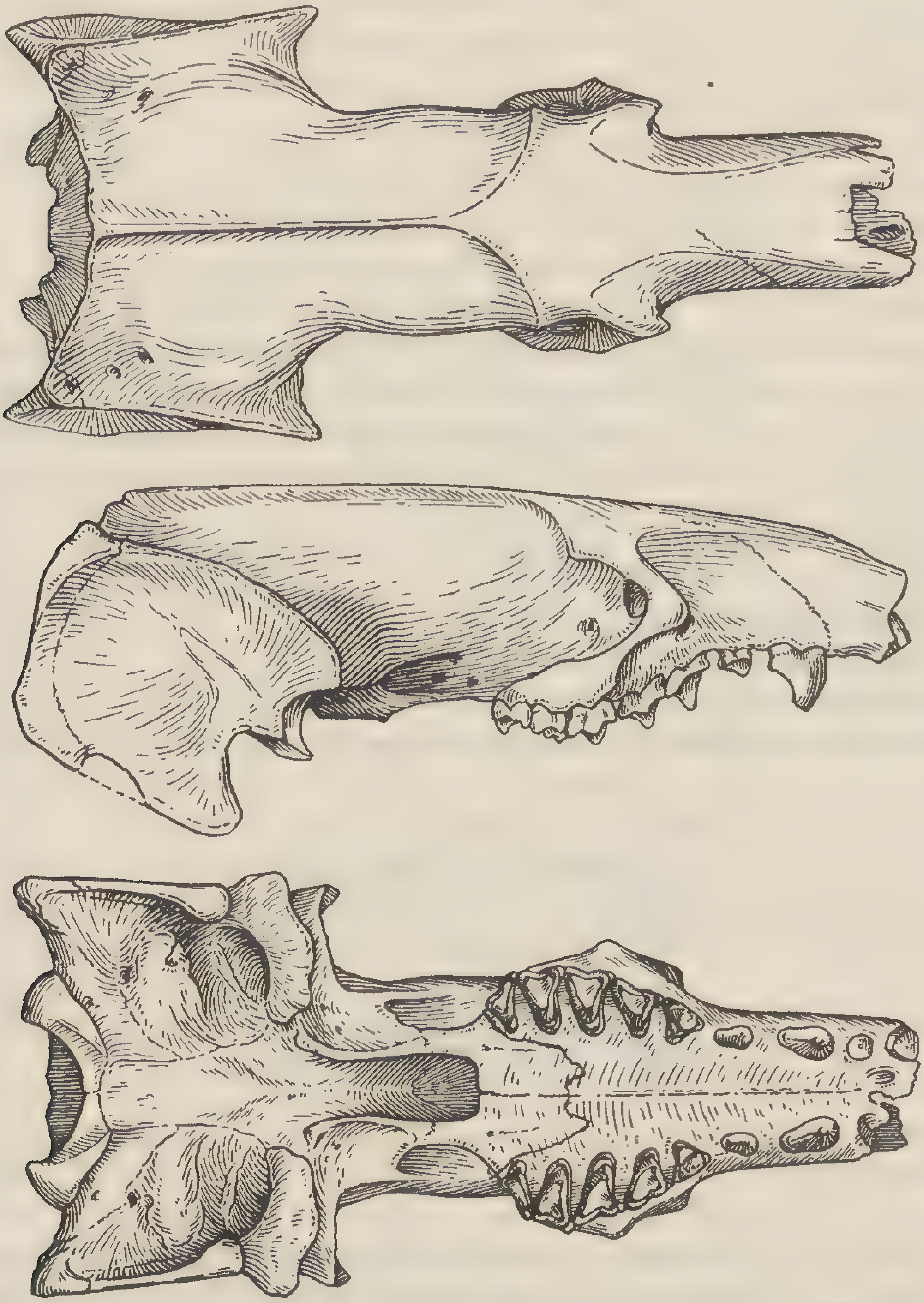

FIG. 3. *Apternodus gregoryi*. Dorsal, lateral and palatal views of the skull. Enlarged two times natural size.

petrosal seems to be well defined. The basisphenoid is flat, as in *Solenodon* and *Microgale*, and bears no pit as does this bone in the skulls of *Centetes*, *Ericulus*, *Echrinops* and *Erinaceus*. It possesses no descending lateral wing embracing the tympanic cavity on the mesial side, unlike the condition in all the recent zalambdodonts with the exception of *Solenodon*.

There seems to be a distinct suture between the petrosal and the exoccipital extending from the basioccipital to the foramen lacerum posterius. The petrosal is in close contact with the basioccipital. The anterior part is concave and forms the dorso-posterior wall of the deep, rounded tympanic cavity. Posteriorly the petrosal is rounded, and postero-externally it presents a knob-like projection. The tympanic is not preserved but it was probably ring-like and was probably braced between the petrosal projection and a rather low swelling which is present on the posterior surface of the post-glenoid process; a condition especially similar to that in *Solenodon*.

Viewed from behind, the skull is bracket-shaped in outline. It is broad and relatively low. Complete sutures between the exoccipital and the mastoid portion of the periotic, between the latter and the supraoccipital, and between the supraoccipital and the exoccipital are not distinct. There is some evidence, however, that their arrangement is as shown in Figure 4. Foramina are absent, and there is a slight depression on the margin of the foramen magnum immediately above the condyle. The squamosal is of peculiar shape in that it is the major element in the plate-like development at the side of the skull. The presence of interparietals cannot be determined. The lambdoid and sagittal crests are prominent and massive. Anteriorly the sagittal crest divides into two low but sharply defined ridges leading to the rudimentary postorbital processes. There is a slight postorbital con-

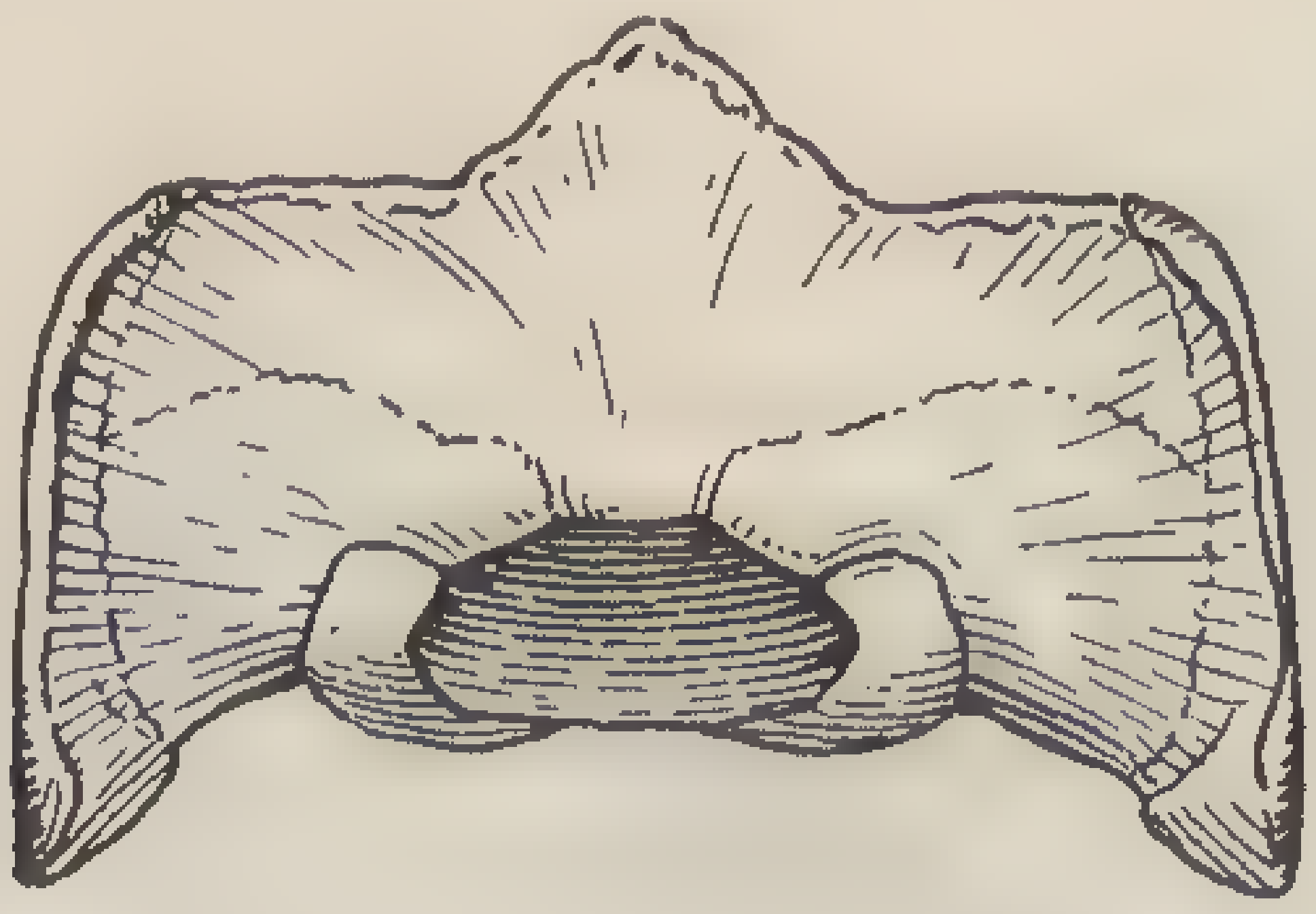

FIG. 4. *Apternodus gregoryi*. Posterior view of the skull. Enlarged two times natural size.

striction. The sutures of the cranium are completely fused. The interorbital region is flattened and broad. The antorbital region is cylindrical, and somewhat broadened anteriorly. The nasals are completely fused. The premaxillary is large and is heaviest in the area of the enlarged incisor. There is a distinct suture on the side of the face between the maxillary and premaxillary. The facial portion of the maxillary presents a relatively large depressed area dorso-anteriorly to the orbit. This depression was undoubtedly occupied by the levator labii superioris proprius muscle, which must have been large. The large size of this muscle may indicate that there was present an extended naso-cartilage similiar to that in *Solenodon*. There is an abrupt transverse constriction of the face across the maxillaries from M^1 to the canine; a condition almost identical with that seen in *Solenodon*. The boundary of the lachrymal cannot be determined. The orbit is diminished, and the antorbital border is bar-like and set out from the plane of the front of the face. The zygomatic arch is completely lacking. The infraorbital portion of the maxillary shows only the slightest indication of a malar projection, and that projection is above the front of M^1. The region of the palate anterior to P^2 is flattened and narrow. Posteriorly the palate is broad, and is concave transversely and antero-posteriorly. It extends behind M^3. The palatines are large and extend forward to M^1. Each has a triangular postero-external wing extending back to meet the pterygoid plates. The exact boundaries of the orbitosphenoid, alisphenoid and vomers are indeterminable.

Cranial Foramina. The infraorbital foramen is situated above the center of P^3. It is large, round and faces forward due to the outward and forward projection of the antorbital border. The infraorbital canal is short.

The lachrymal foramen is round, proportionally large and is marginal in position; facing outward and slightly backward.

The anterior palatine foramina are small and set closely together. The posterior palatine foramina are minute, and occupy a rather postero-mesial position to the last molars.

The spheno-palatine foramen is about equal in size to the optic foramen. The latter is situated immediately and centrally in front of the very large opening formed by the apparent confluence, externally at least, of the foramen lacerum anterius and the foramen rotundum.

The alisphenoid canal is smaller than the foramen ovale and is situated antero-internally to the latter.

The foramen ovale is large, round and is situated near the internal border of the glenoid cavity.

The postglenoid foramen is situated inside and at the antero-external corner of the tympanic pit.

The foramen lacerum posterius is large, round and occupies a position slightly internal to and immediately behind the knob-like projection of the petrosal.

The condylar foramen is small, oval in shape, situated more mesially than the foramen lacerum posterius and is located at the margin of the articular surface of the condyle.

There seem to be only two squamoso-parietal foramina. They are small, oval and are situated antero-internally to the postero-dorsal corner of the plate-like structure at the side of the skull.

Measurements of the Skull

	mm.
Exoccipital condyle to anterior of canine	38.5
Width across post-tympanic processes	19.5
Width across postero-inferior corners of auditory plates	20.0
Greatest length of auditory plate	15.8
Greatest height of auditory plate	13.1
Width of occipital condyles	11.1
Height of occiput, basioccipital to top of saggital crest	11.0
Height of skull above alveoli of M^1	10.4
Front of antorbital ridge to occipital condyle	32.1
Front of antorbital ridge to front of enlarged incisor	11.7
Greatest width across maxillaries above posterior of canines	7.6
Width across maxillaries on postero-external alveoli of Ms^1	13.2
Length of tooth row anterior of canine to posterior of M^3 on alveoli	16.0
Anterior of canine to P^4, inclusive, on alveoli	10.8
Length of canine on alveoli	3.0
Greatest width of canine	1.7
Greatest length of P^4	2.8
Width of P^4 at center of crown on alveoli	3.0
Greatest length of M^1	2.5
Width of M^1 at center of crown on alveoli	3.6
Height of M^1, external	1.2
Greatest length of M^2	1.8
Width of M^2 at center of crown on alveoli	3.4
Greatest length of M^3	1.0
Greatest width of M^3	3.0
Glenoid cavity to occipital condyle	13.5

Lower Dentition. Dental formula $_{2?-1-3-3}$. I_2 is the largest. The crown is broken off, but the stub of the root is oval in outline; being compressed laterally. I_3, the canine and P_2 are missing, the alveoli however, indicate that they were single rooted, round, about the same size, and that they were set close together. P_3–M_3 are two rooted. P_3 is oval in outline and consists of a single, centrally-placed, high, conical cusp, and an anterior and a posterior cingulum. The latter is higher and slightly less developed than the former. P_4 is very molariform and affords a beautiful example, as did the fourth premolar of the upper dentition, of the transition from the premolar to the molar tooth pattern. The trigonid is made up of a high external angular cusp, the probable homologue of the molar protoconid, and an antero- and a postero-internal cusp which correspond in position to the para- and metaconids of the molars. The postero-internal cusp is closely approximated to and almost as high as the external cusp. The antero-internal

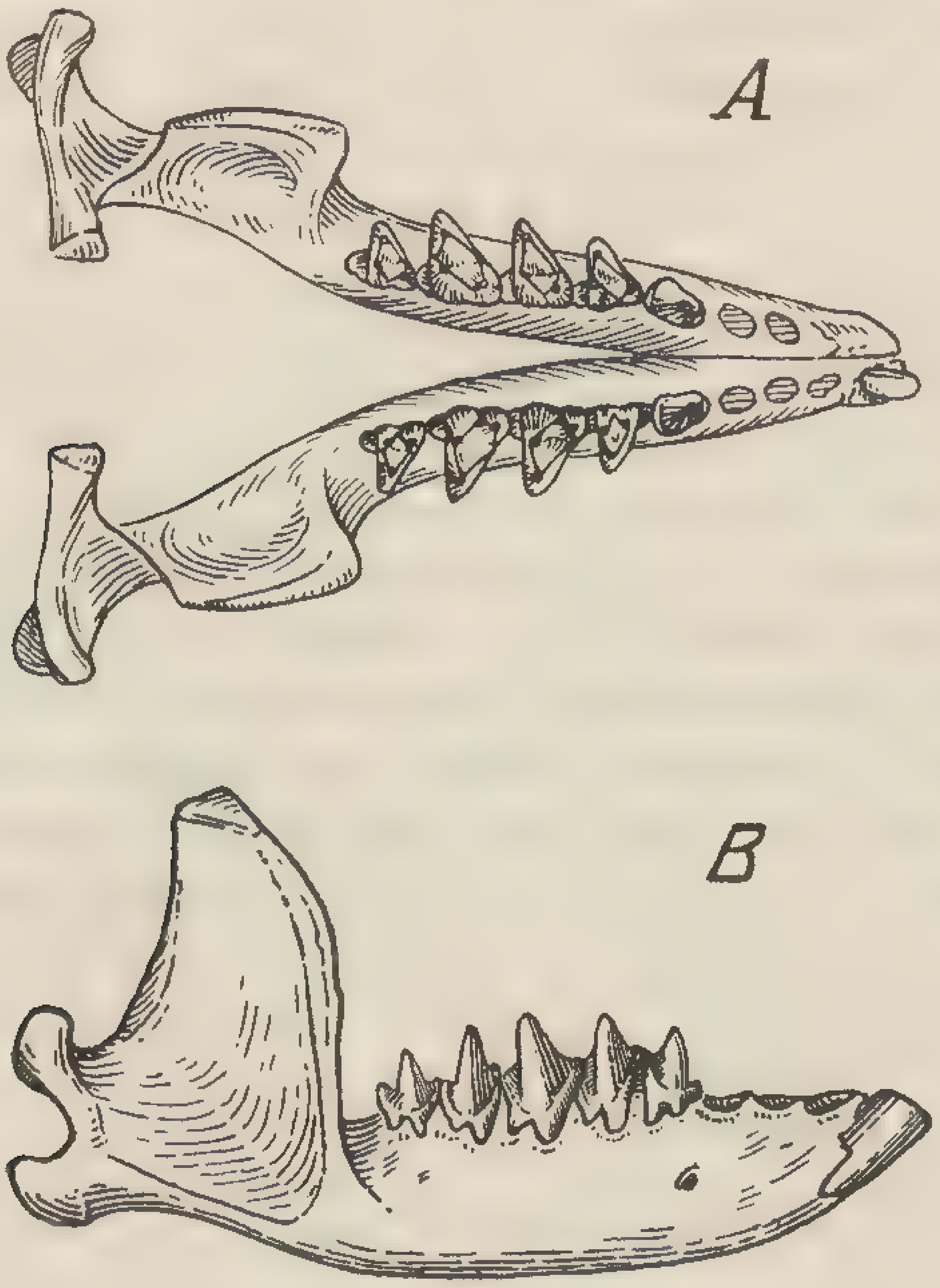

FIG. 5. *Apternodus gregoryi*. *A*, Superior view of jaws. *B*, Lateral view of right lower jaw. Enlarged two times natural size.

cusp is smaller and lower than the other two cusps of the trigonid. There is a small antero-external cingulum. The tooth has a low, minute, posterior heel. M_1 is the largest tooth of the premolar-molar series. It, as well as M_2 and $_3$, are of essentially the same pattern as P_4; the only major difference being the further separation of the protoconid from the metaconid. This results in a widening of the teeth. M_{1-2} are wider than they are long and M_3 is longer than it is wide. The proportional increase of the length of M_3 is brought about by the relative enlargement of the posterior heel. See Figure 5.

The Mandible. The mandible is relatively short and heavy. The symphysis is long — about one-third the length of the entire jaw,— and the rami are not fused. This strengthening of the symphysis is in direct relation to the enlargement of the second lower incisor. The ramus is deep and the posterior mental foramen lies beneath the center of P_3. Just posterior to the tooth row there is a dorso-ventral constriction of the ramus and the posterior part of the jaw is curved upward. The coronoid is very large and stout. It is expanded anteroposteriorly. It is unusually high, is directed upward and forward, and occupies a position external to the tooth row. The angle is small, protrudes slightly behind the condyle, is rounded externally, and is sharply and considerably inflected. The condyle is heavy and broadly expanded transversely. It is horizontal in position and is somewhat elevated above the tooth row. The foramen mandibulare is situated just below and in front of the condyle, and is on the level with the mesial base of the tooth row.

Measurements of the Jaw

	mm.
Posterior of I_2 (on alveolus) to condyle	26.5
Posterior of I_2 to M_3 on alveoli	15.5
M_{1-3} on alveoli	7.0
M_{2-3} on alveoli	4.5
Depth of jaw under center of M_2 (internal)	6.0
Posterior of M_3 to foramen mandibulare	6.5
Height of coronoid from bottom of jaw	13.5
Width of condyle	8.0
Height of M_1	4.5
Antero-posterior length of M_1	2.0
Width of M_1	2.6
Height of M_2	4.0
Antero-posterior length of M_2	1.8

Width of M_2	2.5
Height of M_3	3.0
Antero-posterior length of M_3	2.5
Width of M_3	1.8
Height of P_4	4.0
Antero-posterior length of P_4	1.6
Width of P_4	1.6
Height of P_3	2.6
Antero-posterior length of P_3	2.0
Width of P_3	1.5

AFFINITIES

It is very unfortunate that the type material of the genus *Apternodus* is so fragmentary. There can be little question, however, that the species described above belongs to that genus, and the differences pointed out between *A. mediaevus* and *A. gregoryi*, should, for the present at least, be considered as of specific rather than of generic value. The difference between the two species is mainly one of degree. With the information at hand, it seems that *A. gregoryi* has carried to greater emphasis the specializations already established in *A. mediaevus*, and it is probable that the latter is its direct ancestor.

In 1910 Matthew gave a brief description (pp. 33–36) of an unusually complete insectivore skull and jaw collected from the lower Oligocene, Titanotherium beds "in the neighborhood of Bate's Hole, north of the Laramie Plains" Wyoming (p. 33). He referred this specimen to *A. mediaevus*. The specimen is deposited in the museum at the University of Wyoming, and unfortunately I have not had the opportunity of studying it.[1] Excellent enlarged photographs of it, however, are on file at the American Museum of Natural History. Referring to these and to Matthew's description I have been able to draw the following conclusions. If the explanation of the plate in Matthew's publication is correct,— that the published photographs are three times the natural size of the specimen,— then the University of Wyoming specimen is about two-thirds the size of *A. gregoryi*. If, however, the record with the photograph negatives in the American Museum of Natural History is correct, then the two specimens are approximately of equal size. From an inspection of the photographs, some of the characters in which the University of Wyoming specimen differs from *A. gregoryi* are: postorbital region proportionately much longer; face in front of antorbital bar proportionately shorter; proportionately broader across the auditory region; skull higher above M^2; palate proportionately broader across M^1; length from posterior mental foramen to anterior of base of coronoid process much longer; no diastema between last I and C, and only the slightest diastema between C and P^2 and between P^2 and P^3; M^3 with greater antero-posterior length and with well developed proto-hypocone cusp; and, M^1 with well developed anterior and posterior cinguli. In other respects, such as tooth formula and development of auditory plates at the sides of the cranium, the two specimens are very similar.

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[1] The specimen was reported as lost. It has been found since this manuscript went to press, and the results of a study of it will appear in a subsequent paper.

The problem of the relationship of *Apternodus* to other zalambdodonts is a most interesting one. There has, as yet, been no fossil form recorded, which may be spoken of as being in the direct ancestral line of this genus. *Micropternodus borealis* from the lower Oligocene (a lower jaw described by Matthew, 1903) is the most nearly related. The two genera are similar in the following characters: long symphysis of the lower jaw; high trigonid and low talonid; outline of the trigonid; protoconid the tallest cusp of the trigonid; and, metaconid more emphasized than the paraconid. *Apternodus* is different from *Micropternodus*, however, in the greater massiveness of the mandible, the loss of I_1, the single rooted P_2, the talonid more reduced, and the extreme external displacement of the coronoid process from the tooth row. These two genera do not seem to be very distantly related, and it is probable, I think, that their common ancestor need not have lived earlier than middle or late Eocene times.

The only other known fossil zalambdodont from America is *Palaeoryctes puercenis* (described by Matthew, 1913) from the Paleocene (Torrejon formation) of New Mexico. Dr. Matthew (1913, p. 310–314) considered *Palaeoryctes*, as known, to be a generalized zalambdodont that could have given rise to the diverse modern types. When further discovery reveals more material, however, *Palaeorcytes* may prove to be somewhat specialized (especially in the anterior region of the skull) and off the line of *Apternodus* ancestry, although *Apternodus* must have originated from a form very close to *Palaeoryctes*. As shown by Gregory (1922 p. 156, pl. 5) *Palaeoryctes*, (or its European equivalent, not yet discovered) could well have been the direct ancestor of *Potomogale*. Dr. G. G. Simpson in his very excellent paper on "Affinities of the Mongolian Cretaceous Insectivores" (1928) pointed out that the Deltatheridiidae are near the starting point of the Zalambdodonts.

Deltatheridium, however, was already on the way to give rise to the Creodont type of dentition.

Considering the question of the relationship of *Apternodus* to the recent forms, it seems that *Solenodon*, the Central American zalambdodont, is its nearest living relative. This similarity is established by the following characters which are common to both genera.

1. Slight postorbital constriction.
2. Constriction of the antorbital part of the face; especially the abrupt constriction across the maxillaries from M^1–C.
3. Tendency for the mesial basal cusp on M^2 and especially M^1 to divide into a protocone and a hypocone.
4. Basisphenoid with no pit.
5. Basisphenoid with no lateral descending wing embracing the tympanic cavity on the mesial side (this character is distinctive of *Solenodon* and *Apternodus* among the zalambdodonts).
6. Ring-like tympanic braced between the petrosal projection and the prominence on the postglenoid process. In fact, the entire basicranial region, with the exception of the descending processes of the auditory plates, is almost identical with that of *Solendon.*
7. Long mandibular symphysis, and general shape and massiveness of the mandible.
8. Large, heavy, high and erect coronoid process.
9. Broadly expanded mandibular condyle.
10. Enlarged second lower incisor.

In tooth formula, however, *Apternodus gregoryi* is nearer *Echinops* and *Ericulus,* because of the apparent loss of the first upper and lower incisors. In molar pattern the two latter are quite different from *A. gregoryi* in that the proto- and hypocones are diminutive and are widely separated; being situated on the anterior and posterior sides, respectively, of the para-metacone cusp. In some respects, such as the lack of development of the internal cusp of M^3 and the lack of well defined proto- and hypocones on M^{1-2}, *Microgale* seems to present a molar pattern more like *A. gregoryi* than does *Solenodon.* The premolar-molar teeth of *Solenodon,* however, present no characteristics which could not be derived from the *A. gregoryi* pattern. All in all, it may be said that the similarity of tooth pattern between *Microgale* and

Apternodus, if as great, is not greater than the similarity between that of *Microgale* and *Solenodon* (see Fig. 6).

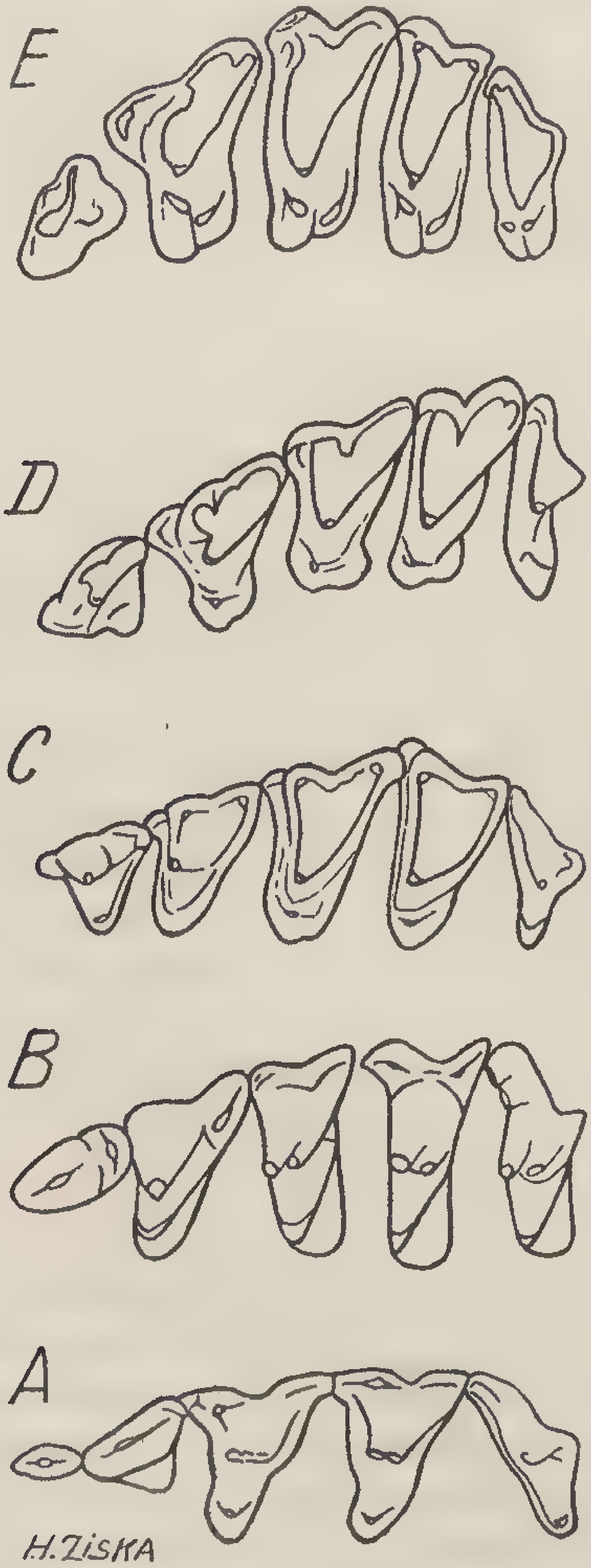


Fig. 6. Comparative drawings of left upper cheek teeth. *A, Deltatheridium pretrituberculare. B, Palaeoryctes puercensis. C, Apternodus gregoryi. D, Microgale dobsoni,* A.M.N.H. No. 31261. *E, Solenodon paradoxus,* A.M.N.H. No. 28270. (*A, & B,* after Simpson.) Not to scale.

In spite of all the above listed similarities between the two genera, *A. gregoryi* cannot hold claim to a place in the direct line of ancestry of *Solenodon*. It presents a number of specialized characters which rule it out of that rank. Those characters are as follows: development of auditory plates on sides of skull, extreme reduction of zygomatic root on maxillary, probable loss of first or third upper incisor, loss of first lower incisor, second lower premolar single rooted, extreme external displacement of coronoid process from tooth row, and extreme widening of the mandibular condyle (both the latter are probably resultant of the broadening of the occipital region of the skull and the development of auditory plates). In 1910, Matthew pointed out, quite correctly I think, that the specializations of *Apternodus* were of subfamily rank and suggested the name Apternodontinae. From the evidence presented above it seems evident that this subfamily should be included in the family Solenodontidae rather than in the Tenrecidae (Centetidae) as suggested by Matthew.

Dobson (1882) defined the family Solenodontidae. Along with a number of distinctive anatomical characters listed, he gave the following skull characters: dentition $\frac{3\text{–}1\text{–}3\text{–}3}{3\text{–}1\text{–}3\text{–}3}$, I_2 deeply grooved internally, P^4 and molars with flat V-shaped crowns and notched external margins, skull with interorbital (postorbital) constriction, and mandibular condyle transversely extended. He also pointed out a number of characters in common with *Myogale* and *Scalops*. Leche (1907, pp. 44–46) felt that Dobson had overemphasized the likenesses of *Solenodon* with the Talpine genera, and listed a number of characters to show the relationship of that genus to the Centetidae. He did not, however, question the fact that *Solenodon* should be placed in a separate family. In 1910, Dr. Gregory, as a result of his careful and detailed study of *Solenodon paradoxus*, listed (pp. 225) several additional skull characters of that genus. Among these are: $I\frac{1}{2}$ much enlarged; pseudoprotocone (protocone) and hypocone forming small distinct cusps; no tympanic wing on the basisphenoid; and petrosal with a small tympanic process. It seems justifiable now to redefine, on the basis of skull characters at least, the family Solenodontidae. Such a definition, together with a definition of the subfamily Apternodontinae and the subfamily Solenodontinae (a new name which I propose) is as follows: *Family Solenodontidae.* Tooth formula $\frac{3\text{–}2?\text{–}1\text{–}3\text{–}3}{3\text{–}2?\text{–}1\text{–}3\text{–}3}$. I_2 enlarged. Protocone and hypocone forming small distinct cusps. No tympanic wing on the basisphenoid. Petrosal with small tympanic process. Slight postorbital constriction. Abrupt constriction across the maxillaries from M^1 to C. Mandibular condyle transversely extended. Large, heavy, high and erect coronoid process.

Subfamily Apternodontinae. Tooth formula $\frac{2?\text{–}1\text{–}3\text{–}3}{2?\text{–}1\text{–}3\text{–}3}$. $I^{2?}$ enlarged.

Development of auditory plates at sides of skull. P_2 single rooted. Extreme external displacement of the coronoid process from the tooth row.

Subfamily Solenodontinae. Tooth formula $\frac{3-1-3-3}{3-1-3-3}$. I^1 enlarged. P_2 two-rooted. Antero-posterior ridge on the talonid confluent with the base of the trigonid.

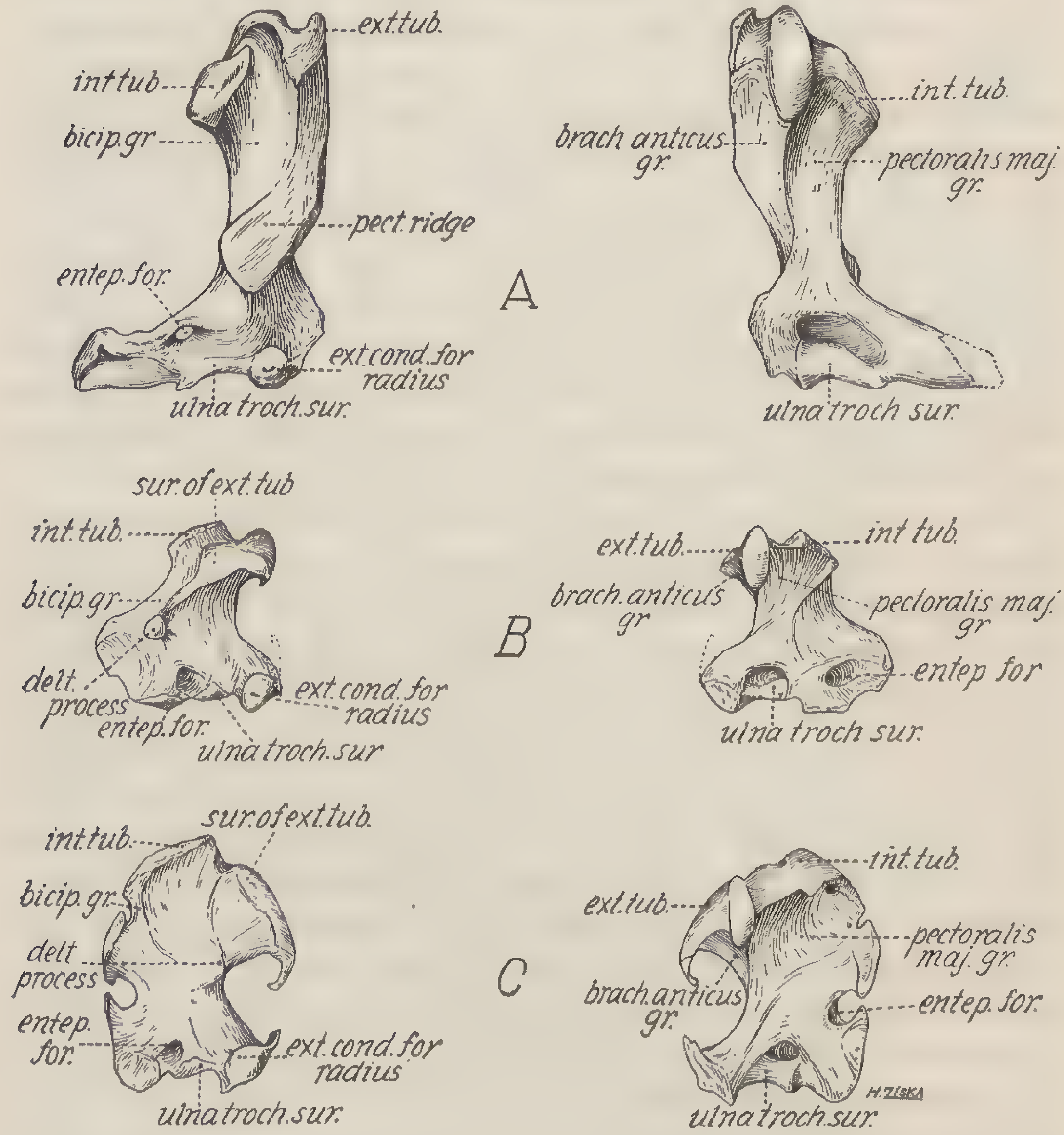
That *Micropternodus* is a zalambdodont has not been questioned. Its exact position in that group, however, has caused considerable speculation. In 1909 (p. 103) Matthew listed it under the insectivores as a member of an indeterminable family. In 1912 (p. 520) Osborn classified it with the Solenodontidae. In 1910 (p. 259) Gregory stated that "*Micropternodus* is also very likely a member of the Centetidae." More recently, Matthew (1919, p. 174) mentioned that it "may have been a distant relative of *Solenodon*." In his description of *Micropternodus* Matthew wrote (1903, p. 205), "P_2 is small and one-rooted, canine small, incisors small, sub-equal. No diastema except a slight one behind P_2." I have examined the specimen, and it is very obvious that the slight diastema behind P_2 of which Matthew spoke, presents a small but very distinct alveolus. P_2 therefore is two-rooted and was probably as large as P_3. The size of the canine alveolus indicates that this tooth was larger than any one of the incisors. Also, I_2 is larger than I_1 or I_3. In comparing *Micropternodus* with *Solenodon*, it is similar to the latter in the following characters: dental formula $_{3-1-3-3}$; I_2 larger than either I_3 or I_1; P_2 two-rooted; antero-posterior ridge on talonid confluent with the base of the trigonid (this especially true of M_3 in *Solenodon*); general shape of the mandible; and the position of the anterior base of the coronoid process (the posterior part of the jaw is missing). These similarities, it seems to me, entitle *Micropternodus* to be placed in the subfamily Solenodontinae along with *Solenodon*. It cannot be said with certainty, however, that *Micropternodus* is or is not directly ancestral to *Solenodon* until more material is discovered. If *Micropternodus* is not ancestral to *Solenodon*, it certainly is not far from a form that is, and if this be true, I can see no reason for placing the common ancestor of that form and *Micropternodus* farther back geologically than latest Eocene.

In this consideration of the relationships of *Apternodus* to other zalambdodonts, mention should be made of two additional fossil forms which have been assigned to the zalambdodont group. They are *Necrolestes patagonensis* from the Miocene of South America, and *Arctoryctes terrenus* from the lower Miocene of South Dakota.

Necrolestes was described by Ameghino in 1891. At that time he pointed out its resemblances to *Chrysochloris*, the Cape golden mole of South Africa. In 1905, Professor W. B. Scott of Princeton restudied the genus, and his conclusions confirmed the suggestion made by Ameghino. He considered *Necrolestes* as a distant relative of *Chrysochloris* (pp. 379–381). In recent years the material at the Princeton Museum was inspected by Dr. G. G. Simpson, and he came to the conclusion that "*Necrolestes* resembles *Chrysochloris* chiefly in adaptive characters in skull and fore-limb, but very significant differences are also seen (the detailed structure of the less plastic parts of the skull is moreover inadequately known), and the pelvis and hind-limb are quite unlike those of the African form. . . . It seems possible that it is a convergent form and not really a member of the *Chrysochloris* group, although apparently an insectivore and perhaps even a zalambdodont" (1927. pp. 294–295). Since there seems to be no conclusive evidence that *Necrolestes* is a zalambdodont, I refrain, for the present at least, from including it in that group.

A left humerus from the lower Miocene of South Dakota was briefly described by Matthew in 1906. The specimen was not figured, and was not given a name until a year later when Matthew, without additional discussion, gave the name *Arctoryctes terrenus* (p. 172). Matthew considered it as positive evidence of the former existence of Chrysochlorids in this country. He further stated that, "The humerus of *Chrysochloris* is, however, so peculiar and characteristic in form, as described by Dobson (Monograph of the Insectivora) and shown in the figures and specimens with which comparison has been made, that there can be no doubt that the fossil specimen belongs to the family, although somewhat less specialized than the modern genus" (p. 787). Recently I have had the opportunity of studying the specimen in detail and I can find hardly the slightest resemblance between it and the humerus of *Chrysochloris*. Dobson's figure of the anterior view of a left *Chrysochloris* humerus to which Matthew referred is shown in Fig. 7A.

The posterior view is from a specimen in the American Museum of Natural History. *Arctoryctes* presents only one major Chrysochlorid similarity,—the large size of the bicipital groove (see Fig. 7B), and this character is certainly not distinctive of the Chrysochlorids. It seems to be Talpine in almost every other respect. Comparing it, for example, with the humerus of *Scalops* the similarities are indeed striking (see Fig. 7C). It is true that the *Arctoryctes* humerus is more expanded distally, and that the deltoid process is more pronounced and occupies a more internal position. Also, the surface of the external tuberosity is more anteriorly placed, hence the insertion for the brachialis anticus is more on the front of the humerus. These differences, however, are only differences of degree. If the external tuberosity were rotated externo-posteriorly, and if the bicipital groove were shortened, a form of humerus would be developed almost identical with the *Scalops* type, although I do not wish to infer by this that *Arctoryctes* is ancestral to the Talpid humerus. The true moles were


ext.tub.
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H. ZISKA

FIG. 7. Anterior and posterior views of left humeri. *A*, *Chrysochloris trevelyani*. Anterior view after Dobson, posterior view A.M.N.H. No. 41500. *B*, *Arctoryctes terrenus* A.M.N.H. No. 12864. *C*, *Scalops* sp. A.M.N.H. No. 36946. Enlarged one and one-half times natural size.

already established in Oligocene times, and the humerus of *Talpa* from the Oligocene of Europe, though slightly more primitive in some respects, is essentially the same as that of the recent form.

Proscalops secundus, a primitive though a somewhat highly specialized pre-talpid occurs in the same geological formation in which *Arctoryctes* was found. Only the skull of this form is known. It is not improbable that *Arctoryctes*, because of its fossorial specializations, is the humerus of that form or one closely related. This suggestion was made by Matthew (1928, p. 71) who stated, however, that "if this be so, *Proscalops, P. secundus* at least, can hardly belong to the Talpidae, but must represent a distinct family." It would seem, that if *Arctoryctes* is the humerus of *Proscalops*, that would be additional evidence for placing *Proscalops* with the Talpids rather than creating a new family for it. The problem of the affinities of *Proscalops*, however, is foreign to the subject of this paper.

It was suggested by Matthew (1928, p. 71) that on the basis of fossorial specializations *Arctoryctes* might be the humerus of *Apternodus*, though the latter had not been found after the lower Oligocene. From what has been said above concerning the affinities of *Apternodus*, it is highly improbable that this form had the *Arctoryctes* type of humerus.

The evidence indicates conclusively, I think, that *Arctoryctes* is not a Chrysochlorid. It seems to be related most nearly to the Talpids, and ought to be included, on the basis of the known material, with that group.

Since *Epoicotherium* (*Xenotherium*), the previously supposed Chrysochlorid from the lower Oligocene, has been shown to be an edentate (Simpson 1927), and since *Necrolestes* and now *Arctoryctes* have also been eliminated from the Chrysochlorid group, there remains no recorded evidence of true Chrysochlorids anywhere in the world with the exception of South Africa where the recent forms occur.

CONCLUSIONS

1. *Apternodus mediaevus* was probably in the direct ancestral line of *A. gregoryi.*

2. Of the known fossil forms, *Micropternodus borealis* is the nearest relative of *Apternodus,* and they probably had a common ancestor in middle or late Eocene times.

3. The *Apternodus-Micropternodus* line was probably derived from a Paleocene form not far removed from *Palaeoryctes. Palaeoryctes,* as pointed out by Simpson, is a probable descendant of the Deltatherididae. Either it or its European equivalent could well have given rise to *Potomogale.*

4. Of the recent zalambdodonts, *Solenodon* is the nearest relative of *Apternodus,* and the latter should be included in the Solenodontidae under the subfamily Apternodontinae.

5. *Micropternodus,* if not the direct ancestor of *Solenodon* is very close to a form that is, and should be included in the same subfamily.

6. *Arctoryctes* is not a Chrysochlorid. It seems, moreover, to be most nearly related to the Talpids. *Necrolestes,* as shown by Simpson, is probably not a Chrysochlorid. Though probably an insectivore, it is not included with the zalambdodonts because of the lack of evidence.

7. There is no recorded evidence of the pre-existence of true Chrysochlorids.

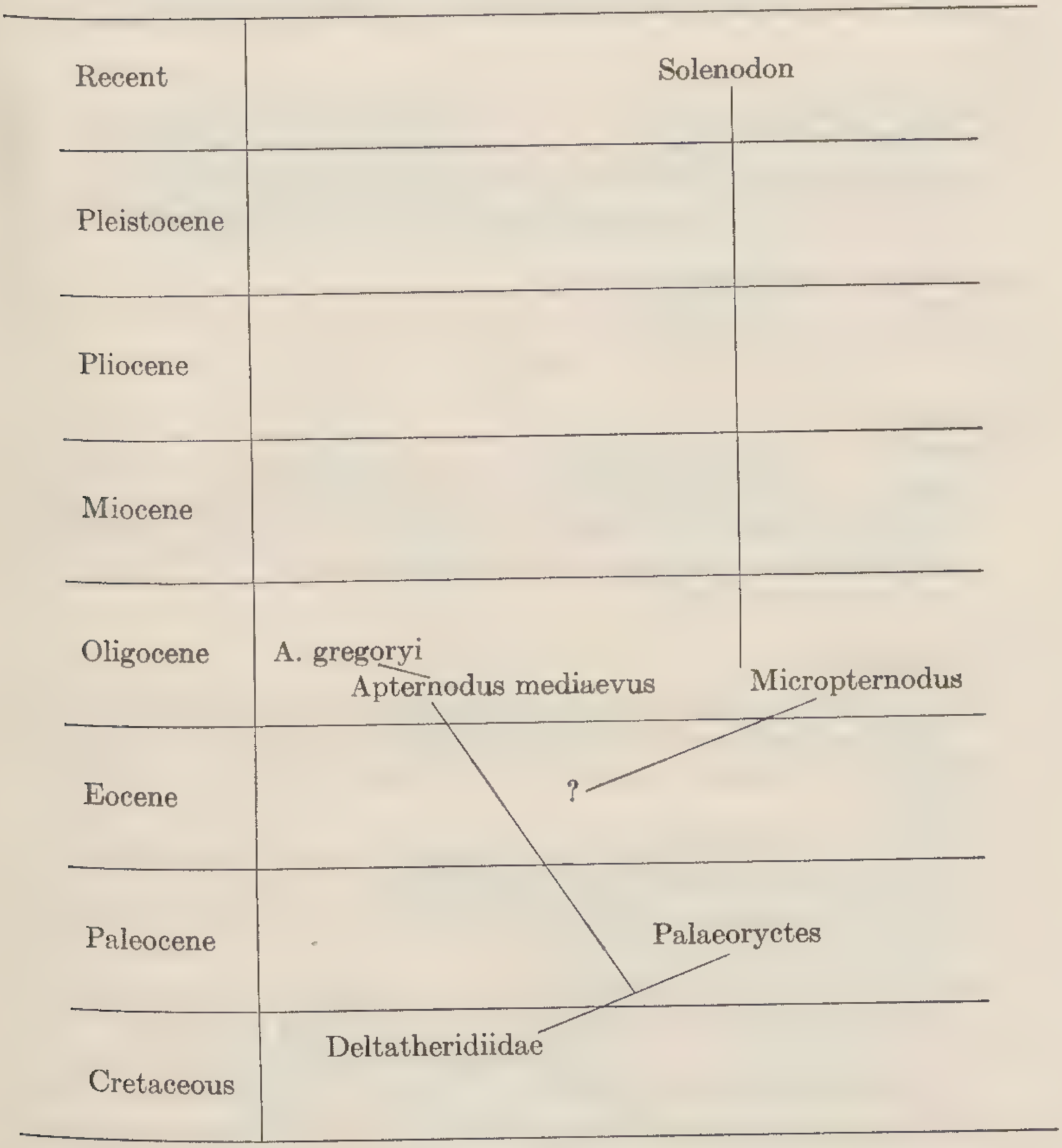
Recent
Solenodon
Pleistocene
Pliocene
Miocene
Oligocene
A. gregoryi
Apternodus mediaevus
Micropternodus
Eocene
?
Paleocene
Palaeoryctes
Cretaceous
Deltatheridiidae

FIG. 8. Diagram illustrating the affinities of the fossil zalambdodont insectivores.

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EXPLANATION OF PLATE

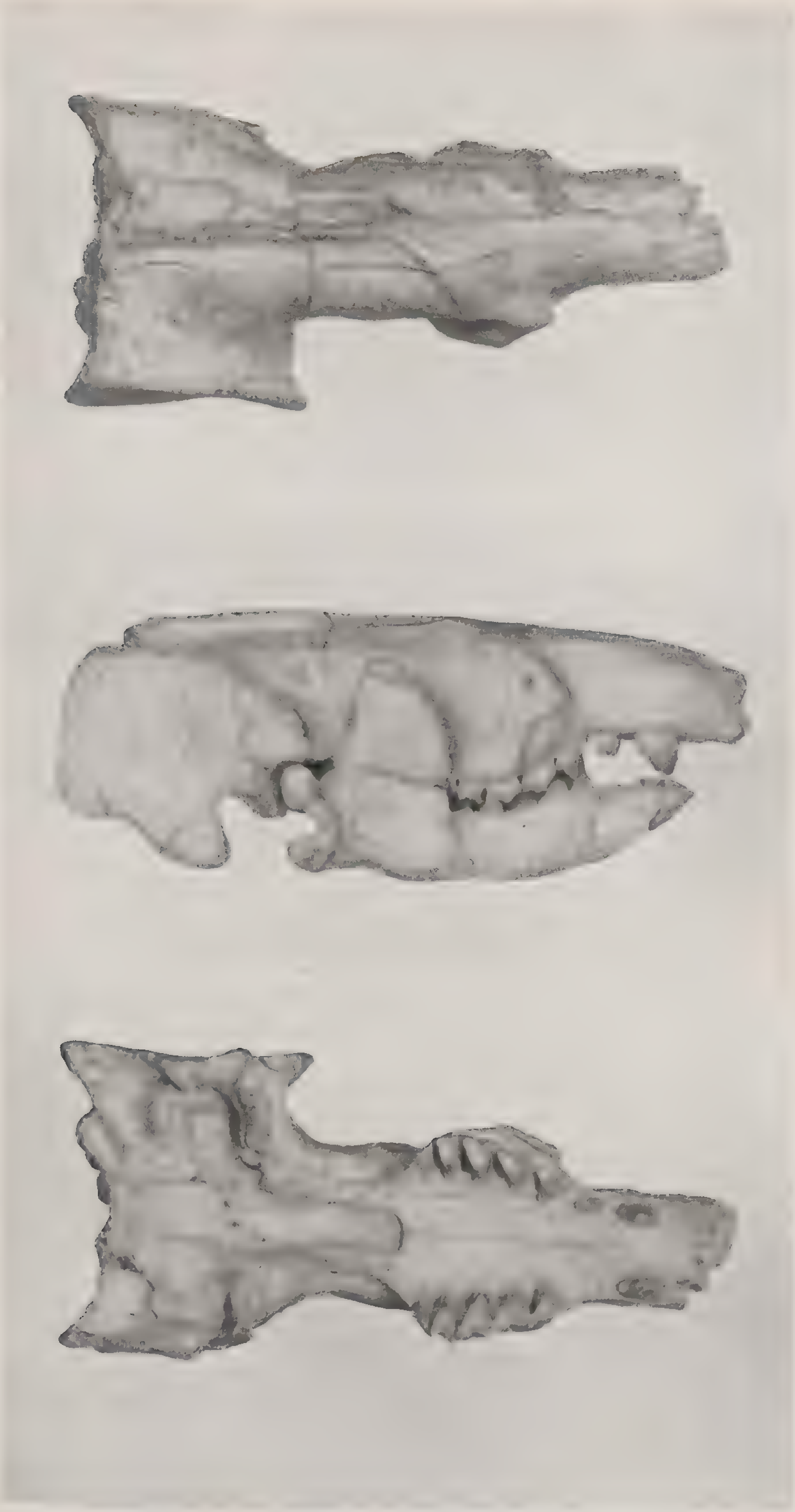
EXPLANATION OF PLATE

Apternodus gregoryi Schlaikjer

Dorsal, lateral, and palatal view of skull. Two and one-quarter times natural size.

Photographs by Albert Thomson.

All figures based on type, M. C. Z. No. 17685.



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AT HARVARD COLLEGE
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CONTRIBUTIONS TO THE STRATIGRAPHY AND PALAEONTOLOGY OF THE GOSHEN HOLE AREA, WYOMING

II

THE TORRINGTON MEMBER OF THE LANCE FORMATION AND A STUDY OF A NEW TRICERATOPS

By Erich M. Schlaikjer

With Six Plates

CAMBRIDGE, MASS., U. S. A.
PRINTED FOR THE MUSEUM
January, 1935

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OF THE

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No. 2.—*Contributions to the Stratigraphy and Palaeontology of the Goshen Hole Area, Wyoming*

II

The Torrington Member of the Lance Formation and a Study of a New Triceratops

By Erich M. Schlaikjer

INTRODUCTION

The present paper constitutes the second part of a series of contributions by the author on the stratigraphy and palaeontology of the Goshen Hole area. This article includes, primarily, a study of the geology and fauna of the Cretaceous formations, with especial attention given to the description of a new continental member of the Lance formation and a study of a new species of *Triceratops.*

Goshen Hole presents approximately two hundred square miles of Cretaceous exposures which have been mapped by the author as part of his field research for the Museum of Comparative Zoölogy at Harvard College during the field seasons of 1930–1933 (Fig. 1). Previous geological work in this area is limited to the reconnaissance by G. I. Adams (published in 1902) on the Patrick and Goshen Quadrangles which includes an eastern strip of the Goshen Hole area. Adam's geological work, however, was not intended to be detailed and while his map of the geology gives the general distribution of the formations in the region concerned, it is not entirely accurate.

I wish to acknowledge my indebtedness to the department of vertebrate palaeontology at the American Museum of Natural History, and particularly to Curator Barnum Brown through whose kind offices I was granted permission to study the very splendid ceratopsian collection in that museum. To Dr. C. W. Gilmore I am indebted not only for his valuable suggestions in the field, but also for the privilege of inspecting the *Triceratops* material in the National Museum. I desire to express my gratitude to Dr. J. B. Reeside, Jr., of the United States Geological Survey for his identification of the invertebrates herein described. Practically every member of the geological faculty at Columbia University has offered valuable criticisms of this paper, and I am especially grateful to Professors

Charles P. Berkey and William K. Gregory under whose immediate guidance this research has been executed.

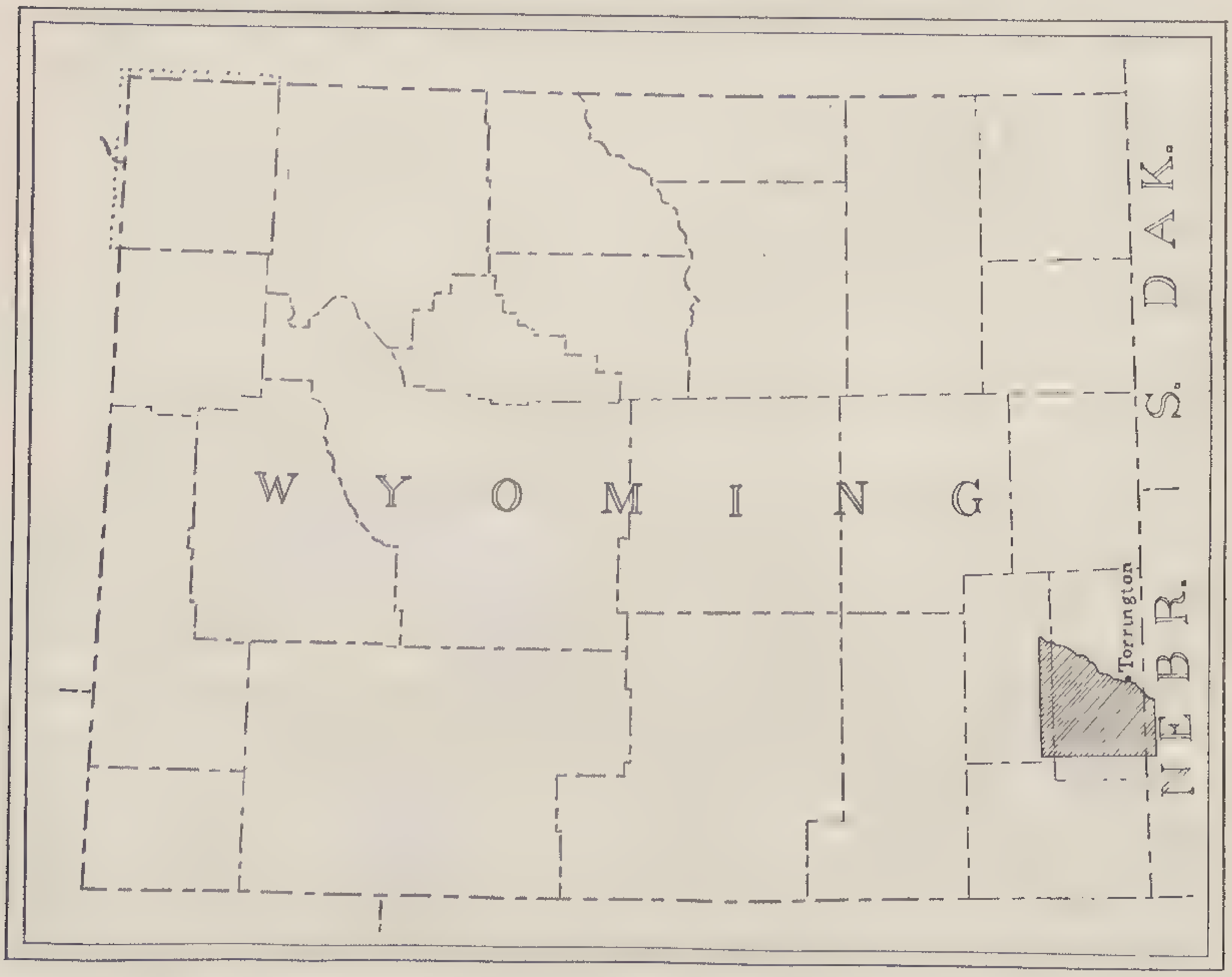

FIG 1. Sketch map of Wyoming showing location of Goshen Hole area.

The ceratopsian remains were most skillfully prepared and mounted for exhibition by Messrs. Charles Lang and Carl Sorensen. The drawings of the *Triceratops* were made by Mrs. Helen Ziska.

DESCRIPTIVE GEOLOGY

General Features

The Cretaceous beds occupy a considerable portion of the interior lowlands of Goshen Hole. As indicated on the accompanying map (Plate 1), two main areas of exposure are present, one in the Corn Creek vicinity to the west and the other principally along Horse Creek. These two areas are separated by a strip of lower Oligocene. Several isolated outcrops of Cretaceous surrounded by Tertiary beds lie immediately to the north and to the east of the main exposures.

Two upper Cretaceous formations are represented in the area. On Corn Creek south of Red-Bill Point is a small exposure of dark gray to black carbonaceous, somewhat sandy shales. The age of these shales will be discussed at length in the succeeding pages. Overlying these shales with an unconformity are the typical yellow, fairly unconsolidated sands and shales, which are Lance in age. Because of the low rounded-hill topography of the Lance beds and because of the abundant alluvium no thick sections are measurable. The general lithology of the formation is that of yellow to greenish sands, yellow, red, green carbonaceous shales and lenticular masses of rather intricately cross-bedded yellow to brown channel sandstones. Occasionally large rounded sandstone concretions, with a diameter as great as two feet occur. On Horse Creek (Sec. 10, T. 22N., R. 61W.) the beds contain a two-foot lenticular layer of lignite coal (see Plate 2) which has been quarried by local people. The coal bed is overlaid by several feet of black shales containing many brackish water invertebrates. Many invertebrate fossils have been found along the banks of Horse Creek from one to three miles southeast of the lignite bed. In places oyster beds assume a thickness as great as twenty feet. These are lenticular, however, and grade laterally into sandstones and thin limestone layers. Near the town of Huntley occurs the same sequence of beds containing many brackish water invertebrates. Throughout the Lance, especially in the Horse Creek vicinity *Halymenites*[1] occurs abundantly. Reptilian remains are abundant in many localities and a very fine skull of a specialized ceratopsian was collected from the reddish shales on the east side of Horse Creek in the NE¼, Sec. 4, T. 22N., R. 61W. The presence of this specialized ceratopsian together with the stratigraphic sequence of the beds and their relation to the remainder of the Lance has made it possible to determine an upper Continental member of this formation which has heretofore been unrecorded.

The Geological Map

Most of the mapping of the Cretaceous beds in the Goshen Hole area was done during the field season of 1931. Detailed mapping of the western-most exposures in the vicinity of Box Elder Creek and Y. B. O. Pass was deferred, however, until the summer of 1933 at which time a topographic survey was made by the author and his party of the western portion of the area. The geologic work was carried on along with this survey, hence enabling more accurate work to be accomplished. The author feels that the accompanying map (Plate 1) presents as accurate a record of the formations as can be made without the use, on a large scale, of unusual methods such as extensive excavating.

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[1] The specimens collected are being studied by Dr. R. W. Brown of the United States Geological Survey who is making an extensive study of this genus.

The accuracy with which the formations could be mapped was, of course, limited. First, while exposures are abundant, they are usually neither thick nor very extensive. Second, alluvium abounds and commonly is of considerable thickness. Third, in many places the contact between the Cretaceous and the overlying Tertiary could not be determined exactly because of the presence of debris which has been transported down from the strata above. In most instances, however, close approximation was possible. In order to cope with these difficulties it was necessary to employ every possible method for determining the character of the subsurface rocks. Particular attention was paid to the type of soils, especially in newly plowed fields. Also, while the field work was carried out, many new county roads were graded, thus affording fresh exposures. Materials along irrigation canals proved very helpful, and frequently the walls of the canals would show splendid exposures. Wherever necessary, diggings from water wells and even cellars were inspected.

No attempt was made to show on the map the separate members of the Lance formation or the alluvial deposits. To do this accurately would have been an endless procedure and perhaps impossible. Only the principal roads, the main irrigation canals and the major topographic features are indicated on the map. A topographic map of the entire Goshen Hole area will appear later.

STRATIGRAPHY

All of the Cretaceous exposures in the area, with the exception of the limited outcrop of dark carbonaceous sandy shales in the N. W.¼ Sec. 28, T. 22N., R. 63W. along Corn Creek, belong to the Lance formation. The dark shales belong either to the Pierre formation, or represent a level which is transitional between the Pierre and the Fox Hills.

Pierre-Fox Hills. Aside from their lithologic character, the dark shales give no evidence of their affinity. The outcrop is very limited and no fossils were found. Additional information[1] has been obtained, however, by the drilling of three core holes in the Red-Bill Point Corn Creek vicinity. Only the driller's logs and not the cores have been studied by the author. He has, however, had the opportunity of inspecting the cuttings from five core holes drilled through the same strata about 15 miles to the north. All of this drilling was carried out for the Phillips Petroleum Company by the same driller with whose terminology the author is perfectly familiar. The first hole in the Corn Creek vicinity was drilled about two hundred yards northwest of the west end of the outcrop and the surface elevation is approximately 4440 feet. The total depth of the hole was 1031 feet.

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[1] Through the courtesy of Mr. Dean A. McGee, Geologist for the Phillips Petroleum Company.

The driller's log is as follows:

NE corner Sec. 29, T. 22N., R. 63W.

Surface	0 — 17
Yellow, some brown	17 — 38
Gray sandy shale	38 — 52
Gray sandy shale	52 — 59
Sticky gray shale	59 — 62
Sticky gray shale	62 — 64
Gray sandy shale	64 — 70
Sticky gray shale	70 — 72
Sticky gray shale	72 — 81
Gray sandy shale	81 — 83
Sticky gray shale	83 — 84
Gray sandy shale	84 — 92
Loose fine sand	92 — 102
Loose fine sand	102 — 110
Gray sandy shale	110 — 112
Gray sandy shale	112 — 114
Dark carbonaceous shale	114 — 120
Dark carbonaceous shale	120 — 123
Gray shale	123 — 125
Sticky dark shale	125 — 126
Gray shale	126 — 130
Gray shale	130 — 133
Gray sand	133 — 136
Gray shale	136 — 138
Hard tan button	138 — 138.1
Gray shale	138.1 — 140
Gray shale	140 — 149
Gray sandy shale with black streak	149 — 150
Gray sand	150 — 153
Gray shale	153 — 159

Gray sandy shale	159 — 160
Gray sand	160 — 168
Sticky dark shale	168 — 170
Sticky dark shale	170 — 173
Gray shale	173 — 180
Gray shale	180 — 185
Sticky dark shale	185 — 186
Gray shale	186 — 189
Sticky dark shale	189 — 190
Gray sandy shale	190 — 205
Sticky dark shale	205 — 209.6
Gray sandy shale	209.6 — 226
Sticky dark shale	226 — 230
Gray sandy shale	230 — 231
Sticky dark shale	231 — 234
Gray sandy shale	234 — 236
Soft gray sand	236 — 243
Soft gray sand	243 — 247
Carbonaceous shale	247 — 248
Gray sandy shale	248 — 248.6
Carbonaceous shale	248.6 — 251
Gray sandy shale	251 — 253
Gray sandy shale	253 — 256
Sticky dark shale	256 — 260
Sticky dark shale	260 — 262
Gray sandy shale	262 — 264
Sticky dark shale	264 — 270
Sticky dark shale	270 — 271
Gray shale	271 — 279
Sticky dark shale	279 — 280
Gray shale	280 — 287
Sticky dark shale	287 — 290
Sticky dark shale	290 — 300
Gray shale	300 — 304
Gray shale	304 — 307.6
Sticky dark shale	307.6 — 314
Gray shale	314 — 319
Sticky dark shale	319 — 321
Gray shale	321 — 324
Gray shale	324 — 330
Sticky dark shale	330 — 343
Sticky dark shale and hard tan buttons	343 — 344
Gray shale	344 — 348
Sticky dark shale	348 — 350
Gray shale	350 — 353

Sticky dark shale—hard tan buttons	353 — 354
Sticky dark shale—hard tan buttons	354 — 358
Gray shale	358 — 359
Gray mostly sand	359 — 361
Gray shale	361 — 362
Sticky dark shale—hard tan buttons	362 — 365
Sticky dark shale	365 — 368
Gray shale	368 — 372
Sticky dark shale	372 — 381
Gray shale	381 — 384
Gray shale	384 — 385.6
Sticky dark shale	385.6 — 388
Fairly sticky gray shale	388 — 394
Fairly sticky gray shale	394 — 395
Sticky dark shale	395 — 399
Sandy gray shale	399 — 405.6
Hard sandy shale	405.6 — 407
Gray sand	407 — 414
Gray sand	414 — 422
Fairly sticky gray shale	422 — 424
Sticky dark shale	424 — 427
Gray shale	427 — 437
Sandy gray—little shale	437 — 440
Sticky black shale	440 — 441
Sandy gray shale	441 — 447
Sticky black shale—little coal	447 — 454
Sticky black shale	454 — 458
Sandy gray shale	458 — 465
Gray sand with black streaks	465 — 470
Sticky dark shale	470 — 476
Black almost coal	476 — 477
Sticky dark shale	477 — 479
Sandy gray shale	479 — 484
Soft gray sand	484 — 494
Soft gray sand	494 — 518
Solid gray sand	518 — 519
Hard bluish gray lime	519 — 520.6
Solid gray sand	520.6 — 523
Soft gray sand	523 — 534
Soft gray sand	534 — 544
Sandy gray slate	544 — 545
Soft gray sand	545 — 554
Soft gray sand	554 — 560
Sticky dark shale	560 — 564
Soft gray sand	564 — 574

Soft gray sand	574 —	576
Hard gray lime	576 —	576.8
Soft gray sand	576.8 —	584
Soft gray sand	584 —	585
Sticky dark shale	585 —	599
Gray sandy shale	599 —	600
Sticky dark shale	600 —	602
Gray sandy shale	602 —	607
Black shale and coal	607 —	609
Gray shale	609 —	614
Sticky dark shale	614 —	615
Gray shale	615 —	617
Sticky dark shale	617 —	620
Sandy gray shale	620 —	625
Soft gray sand	625 —	641
Sticky dark shale	641 —	647
Black shale and coal	647 —	649
Sandy gray shale	649 —	657
Dark shale	657 —	658
Sandy gray shale	658 —	661
Dark shale	661 —	662
Sandy gray shale	662 —	667
Sandy gray shale	667 —	672
Sticky dark shale	672 —	672.6
Black shale and coal	672.6 —	673
Sticky dark shale	673 —	676
Sandy gray shale	676 —	678
Sticky dark shale	678 —	683
Sandy gray shale	683 —	684
Sticky dark shale	684 —	688
Sticky dark shale	688 —	698
Sticky dark shale	698 —	709
Sandy gray shale	709 —	713
Soft gray sand	713 —	755
Sticky dark shale—tan buttons	755 —	756
Sticky dark shale	756 —	760
Sandy gray shale	760 —	762
Sticky dark shale	762 —	770
Coal	770 —	770.4
Sticky dark shale	770.4 —	771
Sticky dark shale	771 —	782
Tan buttons	782 —	782.1
Sticky dark shale	782.1 —	786
Gray sandy shale	786 —	787.6
Sticky dark shale	787.6 —	791

Sticky dark shale—tan buttons	791 — 798
Sticky dark shale	798 — 802
Tan button	802 — 802.2
Sandy gray shale	802.2 — 808
Sandy gray shale	808 — 809
Tan button	809 — 809.2
Gray sand	809.2 — 811
Black shale and coal	811 — 811.4
Gray sand	811.4 — 813
Sandy gray shale	813 — 815
Sandy gray shale	815 — 820
Sticky dark shale	820 — 821
Sticky dark shale	821 — 831
Sticky dark shale	831 — 835
Sticky dark shale—little coal	835 — 854
Sticky dark shale—tan buttons	854 — 855
Sandy gray shale	855 — 861
Hard gray lime	861 — 861.8
Sandy gray shale	861.8 — 872
Extra hard tan streak	872 — 872.1
Sticky dark shale	872.1 — 882.4
Sticky dark shale—tan buttons	882.4 — 883
Sticky dark shale—tan buttons	883 — 890
Gray sand	890 — 896.6
Hard broken gray sandy lime	896.6 — 897
Gray sand	897 — 911
Hard bluish gray lime	911 — 914
Sandy gray shale	914 — 925
Sticky dark shale	925 — 932.4
Sticky dark shale—tan buttons	932.4 — 933
Sticky dark shale—tan buttons	933 — 951
Sandy gray shale	951 — 958
Sticky dark shale and coal	958 — 961
Sticky dark shale—tan buttons	961 — 968
Sandy gray shale	968 — 979
Sticky dark shale	979 — 983
Sandy gray shale	983 — 1001
Hard gray lime	1001 — 1002.6
Sandy gray shale	1002.6 — 1003.8
Hard gray lime	1003.8 — 1006
Sandy gray shale	1006 — 1018
Sticky dark shale—hard tan streaks	1018 — 1031

An analysis of this section shows that the first twenty-one feet under the surface material are unquestionably Lance and can be traced as a continuation of the same beds in which were found ceratopsian bones about a mile to the southeast. Approximately one-fifth of the entire section is sand. Sandy shales and sticky black shales abound and some coal is scattered throughout the entire section. There seems to be little evidence of distinct lithologic breaks other than the presence of marked sand-bearing zones. The most pronounced of these zones is the one at a depth of 407 to 585 feet. Of this 178 feet the last 100 feet is almost entirely sands and sandstones. From this depth downward the shales become less and less sandy, and in the last 120 feet there are no sands and sandstones present.

Another core hole was drilled about four miles northeast of the first. The surface elevation is approximately 4320 feet and the total depth of the hole is 602 feet.

The following is the driller's log:

Center of So. Line, Sec. 1, T. 22N., R. 63W.

Surface	0 — 2
Variegated shale	2 — 19
Yellow sand	19 — 28
Hard reddish yellow broken line	28 — 28.6
Variegated sticky shale	28.6 — 49
Yellow sandy shale	49 — 52
Variegated sticky shale	52 — 59
Dirty yellow sand	59 — 71
Sticky dark shale	71 — 76
Mucky fine yellow sandy shale	76 — 79
Dark shale	79 — 82
Dark shale—some hard tan thin streaks	82 — 90
Sandy dark shale	90 — 91
Sandy gray shale	91 — 113
Sticky gray shale	113 — 145
Sandy gray shale	145 — 150
Sticky gray shale—few thin hard tan streaks	150 — 178
Sandy gray shale	178 — 182
Sticky gray shale	182 — 190
Sticky gray shale	190 — 195
Coal	195 — 195.1
Sticky gray shale	195.1 — 200
Sticky gray shale	200 — 206
Fine gray sand	206 — 215
Sandy gray shale—much coal in thin layers	215 — 227
Soft gray sand	227 — 236
Fine sandy gray shale	236 — 243

Sticky gray shale—some hard tan streaks	243 — 268
Soft gray sand	268 — 272
Sandy gray shale	272 — 280
Sticky gray shale—little coal	280 — 290
Sticky gray shale—little coal	290 — 300
Sticky gray shale	300 — 324
Sandy gray shale	324 — 331.8
Bluish gray lime	331.8 — 332.6
Soft gray sand	332.6 — 334
Soft gray sand	334 — 342
Sandy gray shale—some hard tan streaks	342 — 347
Sticky gray shale	347 — 358.9
Hard gray lime	358.9 — 359.3
Sticky light gray shale	359.3 — 361.3
Sticky gray shale	361.3 — 419.7
Extra hard dark chert-like lime	419.7 — 420.9
Sticky gray shale—some hard tan streaks	420.9 — 458
Sandy gray shale	458 — 477.6
Sandy gray lime	477.6 — 478
Sandy gray shale	478 — 503
Mucky dark shale	503 — 506
Sticky gray shale—some thin hard tan streaks	506 — 540
Sticky gray shale	540 — 543
Sandy gray shale	543 — 543.3
Sticky gray shale	543.3 — 550
Sticky gray shale—many hard tan streaks	550 — 582
Hard gray lime	582 — 582.8
Sticky gray shale—hard tan streaks	582.8 — 592
Sticky gray shale	592 — 600
Sticky gray shale—hard tan streaks	600 — 602

The first 79 feet of this hole is typical Lance. The rest of the log shows remarkably few sand and sandstone layers. The first layer of sand occurs at a depth of 206–215 feet. The only satisfactory correlation which can be made with the first core hole is that this sand layer is the equivalent of the 18 feet of soft gray sand at a depth of 92–110 feet. Such a correlation is in keeping with the general lithologic similarity of the remainder of the hole with that of the first. The total depth of the hole was only 602 feet, hence the thick sand and sandstone layer present in the first core hole, on the basis of this correlation, was not reached.

The following is the log of the third core hole which is located just to the south of Red-Bill Point. Drilling was started at the surface elevation of 4380 feet.

NW¼, Sec. 4, T. 22N., R. 63W.

Surface	0 — 12
Sticky pink and yellow shale	12 — 16
Broken reddish yellow lime	16 — 21
Yellow sand	21 — 36
Sticky yellow shale	36 — 48
Sticky yellow shale—greenish-blue streaks	48 — 60
Sticky yellow shale	60 — 64
Yellow sand	64 — 67
Sticky yellow and gray shale	67 — 71
Sticky gray shale	71 — 75
Red sandy soft	75 — 76
Sticky gray shale	76 — 79
Red sandy soft	79 — 79.6
Sandy gray shale	79.6 — 80
Fine sandy-gray shale	80 — 81
Fine sandy gray shale	81 — 88
Sticky gray shale	88 — 91
Fine sandy gray shale	91 — 110
Fine yellow sand	110 — 140
Sandy gray shale	140 — 143
Fine sand—variegated	143 — 148.8
Sandy gray shale	148.8 — 150
Reddish yellow coarse sand	150 — 167
Reddish yellow coarse sand	167 — 175
Sticky gray shale	175 — 176
Sticky gray shale—little coal	176 — 181
Reddish brown sandy shale	181 — 182
Sticky gray shale	182 — 185
Fine sandy gray shale	185 — 211.6
Gray lime	211.6 — 212
Medium coarse gray to white sand	212 — 231
Sticky gray shale—thin coal streaks	231 — 246
Gray sand	246 — 250
Gray sand	250 — 251
Gray shale	251 — 252
Soft gray sand	252 — 253
Gray shale	253 — 255
Gray shale—coal streaks	255 — 262
Fine light gray sand	262 — 265
Gray sand	265 — 285
Fine sandy gray shale	285 — 288
Fine sandy gray shale	288 — 295
Fairly sticky gray shale	295 — 296

Fine sandy gray shale	296 — 298
Fine sandy gray shale	298 — 302
Mostly coal	302 — 303
Fine sandy gray shale—little coal	303 — 321
Hard white quartz-like lime	321 — 321.5
Fine sandy gray shale—some thin layers of coal	321.5 — 390
Fine sandy gray shale	390 — 400
Fine sandy gray shale	400 — 418
Gray sand	418 — 440
Fine sandy gray shale	440 — 488.6
Cherty bluish-gray lime	488.6 — 488.9
Extra hard chert-like bluish-gray with black streaks of lime	488.9 — 490.4
Hard tan streak	490.4 — 490.6
Soft gray sand with many black specks	490.6 — 499
Gray sand	499 — 522
Gray shale—thin coal streaks	522 — 545.6
Extra hard rough tan streaks	545.6 — 546
Sandy gray shale—little coal	546 — 550
Sandy gray shale—little coal	550 — 602
Sandy gray shale—little coal	602 — 612
Fine sandy gray shale	612 — 613
Sticky gray shale	613 — 614
Gray sand	614 — 615
Fairly sticky gray shale—tan buttons	615 — 622
Sticky gray shale	622 — 629
Sticky gray shale—broken tan buttons	629 — 630
Sticky gray shale	630 — 640
Gray shale	640 — 643
Hard chert-like bluish gray lime—black streaks	643 — 643.4
Sticky gray shale—some hard tan buttons	643.4 — 653
Sandy gray shale	653 — 655
Sticky gray shale	655 — 657
Gray sand	657 — 658
Sticky gray shale	658 — 658.6
Tan buttons	658.6 — 659
Sandy gray shale	659 — 663
Tan buttons	663 — 663.6
Sticky dark shale	663.6 — 666
Soft gray sand	666 — 669
Sandy gray shale	669 — 670
Sticky gray shale	670 — 678
Dark carbonaceous shale	678 — 686

Since the remains of *Triceratops* and *Trachodon* were found a mile to the east in beds which can be traced as the equivalent of the upper thirty feet of this section and since all of the first 180 feet seem to be a lithologic unit, it seems logical to refer to this as unquestionably Lance. At depths 212 — 231 feet occurs a medium coarse white sand. This sand was not encountered in either of the other core holes. The only satisfactory correlation which can be made of the remainder of the hole with that of the first on Corn Creek is that the 32-foot layer of gray sand at depth 490 feet is the possible equivalent of the first sand layer at the 92-foot depth in hole number one.

The data presented in the three core holes gives evidence of a considerable anticlinal structure in the Corn Creek vicinity. In hole number two the strata are structurally 234 feet lower than in one, indicating a gentle dip to the northeast. This is in keeping with surface conditions which show an anticlinal structure plunging to the northeast. Under a special topic, the structural conditions of the region will be considered more fully. In hole number three, the strata are structurally at least 458 feet lower than they are in one, which is a little less than four miles away. This, of course, does not represent the maximum dip since, in relation to hole number one, number three was not located at right angles to the strike of the fold.

Lance. Unconformably overlying the dark carbonaceous sandy shales, on Corn Creek are from seven to ten feet of darkish yellow sandy shales. Immediately above this are twenty to thirty feet of reddish yellow coarse sands more or less consolidated. In these sands, fragmentary remains of large ceratopsians were found. The succeeding one hundred and fifty feet is composed primarily of alternating beds of yellow sands and sandstones, more or less intricately crossbedded, and variegated shales. Bones of *Triceratops* and *Trachodon* are scattered through this series and are especially abundant near the top.

Along Horse Creek good exposures are numerous although no thick sections are measurable. Local correlation is possible, however, and a fairly thick series, 150 to 200 feet, is determinable. In the northwest corner of the SW¼, Sec. 14, T. 22N., R. 61W., on the south side of Horse Creek the following section is characteristic:

	Feet	Feet above Horse Creek
Alluvium		
Gray finely laminated sandstone	1	73½
Concretionary yellow gray limestone	½	72½
Purplish shale	3	72
Yellow sands	2	69
Iron-stained limestone, many brackish water fossils	½	67
Yellowish gray limestone, large Pelecypods	½	66½
Purplish shale	2	66
Gray massive sandstone	2	64
Gray concretionary sandstone	1	62
Gray massive sandstone *Ostrea*	2	61
Gray finely-bedded sandstone *Ostrea*	1	59
Yellow, purple and reddish shale	2	58
Gray finely bedded sandstone	1	56
Gray, purple, red and yellow shale	4	55
Finely bedded gray sandstone	1	51
Yellow and purple shales	4	50
Finely bedded gray sandstone	2	46
Massive gray sandstone	½	44
Finely bedded dark gray sandstone	2½	43½
Red, purple and yellow shales	7	41
Massive gray sandstone	8	34
Finely laminated gray sandstone	1	26
Yellow platey sandstone	2	25
Yellow, purple and red shales	23	
Concealed by water of Horse Creek		

One of the most outstanding features of this section is the presence of the brackish water fossils, *Corbicula, Ostrea,* etc. These fossil-bearing strata are found about a mile to the east in W½, Sec. 13, T. 22N., R. 61W. On the south side of the Creek the *Ostrea* beds are fifteen to twenty feet in thickness. They are lenticular and thin out into gray sands and thin yellowish limestone, which contain *Halymenites.* Four feet of finely bedded reddish yellow and gray sandy shales overlie the oyster beds. About a mile and a half northeast of the town of Huntley, NW¼, Sec. 19, T. 23N., R. 60W., the oyster bed is about three feet in thickness and contains considerable gray and yellow shale and sandy material. Above the oyster layer are seven feet of finely bedded reddish yellow and gray sandy shales which are succeeded by a two-foot layer of finely bedded yellow sandstone. This sandstone contains at the bottom a four-inch layer of brackish water fossils.

One mile northwest, SW¼, Sec. 10, T. 22N., R. 63W., of the locality of the first section given above, the following section was measured:

	Feet	Feet above Horse Creek
Alluvium		
Finely bedded red, yellow and gray sand shale with thin sandstone layers	10–15	41–
Yellow sandstone	2– 5	26–
Greenish-yellow sands with sandstone lens and becoming shaly at bottom	15	21
Dark carbonaceous shale with many brackish water fossils, *Corbula*, etc.	2	6
Lignite	2	4
Dark shales	2+	
Concealed by water of Horse Creek		

The *Corbicula* zone was not found in this locality. A slab of sandstone containing a dozen or more specimens belonging to this genus was found on the surface, however, indicating perhaps that it had come down from the overlying beds which are covered with alluvium. If such is the case, the lower twenty-five feet of this section, or perhaps all of it, is stratigraphically below the beds exposed a mile to the southeast. The beds here dip 4° northwestward for about a hundred yards where they are interrupted by a minor normal fault, which has a southeast dip. There is arching of the strata to the southeast so that within a mile they are dipping gradually to the southeast. Northwestward there is a gradual dip away from the fault, so that the beds exposed here are beneath the surface a mile and a half up Horse Creek, NE¼, Sec. 4, T. 22N., R. 61W., where the following section was studied.

	Feet	Feet above Horse Creek
Alluvium		
Red, yellow and green carbonaceous shales with lenses of sands and sandstones	15	56
Yellow sandstone grading laterally into variegated shales with *Triceratops*	5	41
Green, yellow and gray sands grading laterally into variegated shales containing sandstone lenses and many iron concretions. Abundant remains of large *Triceratops* and *Trachodon*	12	36
Red, green and yellow finely bedded shales and sandstones. *Trachodon*, *Triceratops*, Crocodilian, and turtle remains	10	24
Yellow paperish sandstone	2	14
Greenish-yellow and gray sands	5	12
Yellow sandstone	2	7
Greenish-yellow and gray sands	5+	
Concealed by water of Horse Creek		

The dinosaur remains in these strata are of primary importance. In the lower part of the uppermost twenty feet of this section the skull and some skeletal parts of a new species of *Triceratops* were collected. This individual, to be described in detail under a special topic in this paper, represents the last recorded survivor of that great group of dinosaurs. The presence of this specialized *Triceratops* in addition to the presence of the brackish water fauna which probably is stratigraphically above the *Triceratops* beds of the Lance in other areas, makes it necessary to give a new name to the continental deposits above the *Corbicula-Ostrea* zone. I suggest that it be known as the Torrington member of the Lance Formation,— so named because of its proximity to the established and prosperous town of Torrington, Wyoming, which is located on the North Platte river north of the typical exposures on Horse Creek.

About a mile northeast of Fox Creek Gap, SW¼, Sec. 1, T. 20N., R. 63W., the following section was measured.

	Feet
Yellow and gray cross-bedded sandstone	2
Red, purple and yellow carbonaceous shales *Trachodon* and *Triceratops* remains	18
Yellow cross-bedded sandstone	4
Yellow sands	1
Brown sandstone with cannon-ball concretions 2′ in diameter	2
Yellow and purple sands	4
Yellow and gray platey sandstone	1
Yellow sands	5+
Concealed	

The eighteen feet of red, purple and yellow carbonaceous shales contain fragmentary remains of *Triceratops* and *Trachodon*. The close similarity both in lithology and in the fossils between these shales and those on Horse Creek seem to indicate that the Torrington member is represented in the Fox Creek Gap vicinity. This conclusion is expressed tentatively in Fig. 2.

A mile northwest of Table Mountain, Sec. 17, T. 22N., R. 60W., there is an exposure of yellow and brown sands with large elongate and cannonball concretions of sandstone very similar to those near Fox Creek Gap. Above are five feet of purple shale with many thin limonitic layers, one foot of gray sand and sandstone and finally, five feet of yellow-gray lenticular channel sandstone. Above this sandstone are the typical lower Oligocene clays of the Chadron formation containing titanothere remains (See fig. 2 and plate 3).

Correlation. While long range correlations, based on lithology alone, are inadvisable, it is the only method which can be used to determine the age of the dark carbonaceous sandy shale in Goshen Hole. In this particular instance, however, this method is unusually reliable. Considering first the possibility of the entire series being Lance some serious objections are immediately encountered. First, the Lance is typically made up of yellow, brown, tan and reddish sands, sandstones and shales, and while dark members are frequent they are always relatively thin. These dark sands and shales are over 1000 feet thick as recorded in one of the core holes. Nowhere in the Dakotas, Montana, Colorado, or Wyoming has a single dark member of this magnitude been recorded as belonging to the Lance. Furthermore, if these dark shales and sands belong to the Lance, they ought to be underlain by the typical buff and brown sandstones and shales or *Triceratops* member. Beneath this member should be the typical white and brown members of the Fox Hills formation. On Rawhide Creek about eighteen miles north of Corn Creek a deep test well was drilled, having a total depth of 5628 feet; in Sec. 24, T. 26N., R. 62W. and no such sequence was encountered. In this well, of which only the driller's log is available, the Lance is typically represented by about 440 feet, beneath which is at least 200 feet of typical Fox Hills which in turn grades into the Pierre below.

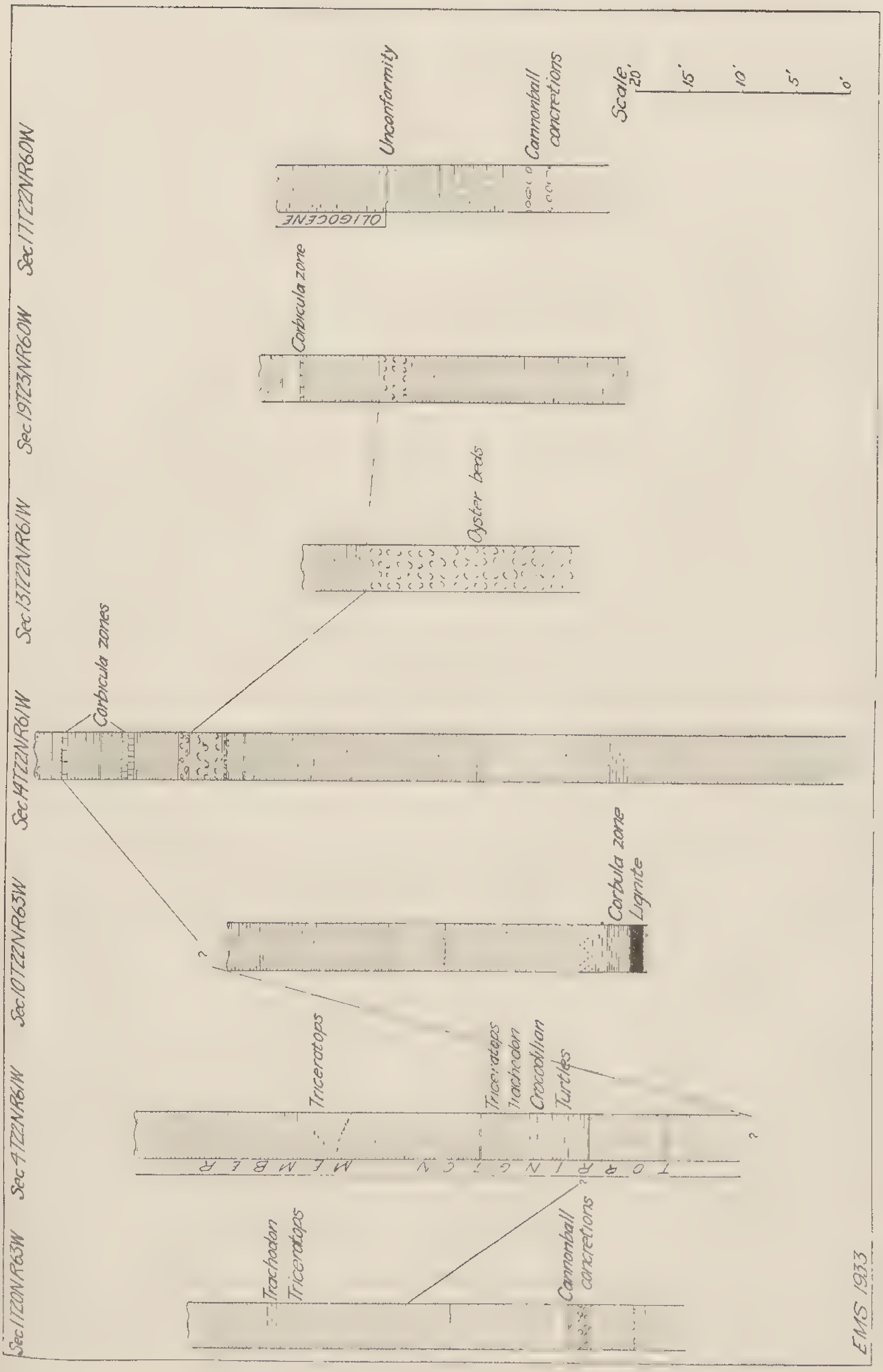
Sec 17 T20N R63W
Trachodon
Triceratops
Cannonball concretions
Sec 4 T22N R61W
Triceratops
Triceratops
Trachodon
Crocodilian
Turtles
TORRINGTON MEMBER
Sec 10 T22N R63W
Corbula zone
Lignite
Sec 14 T22N R61W
Corbicula zones
Sec 13 T22N R61W
Oyster beds
Sec 19 T23N R60W
Corbicula zone
Sec 17 T22N R60W
OLIGOCENE
Unconformity
Cannonball concretions
Scale
20'
15'
10'
5'
0'
EMS 1933

FIG. 2. Columnar sections of the Lance in the Horse Creek vicinity showing lithology and correlations. Schlaikjer 1933.

That the dark shales and sands in Goshen Hole are Fox Hills in age is very questionable. Certainly they are not lithologically the same as the upper Colgate white sandstone and the lower brown members, which characterize the Fox Hills in practically every locality, wherever seen in the field by the author, and as set forth by Meek and Hayden 1861, Cross 1889, Hatcher 1893, Knowlton 1909, Stanton 1909, 1910, Lloyd 1914, Lloyd and Hares 1915, Winchester, etc. 1916, Thom and Dobbins 1924, and Dobbins and Reeside 1929. It is generally agreed, however, that the Fox Hills and Pierre are transitional (Stanton 1910, Ward 1924, Dobbins and Reeside 1929, and others). That the series in Goshen Hole represents a Fox Hills-Pierre gradational sequence, similar to that which occurs in the Salt Creek oil field and in the Poison Spider district west of Casper, is not improbable. Although most of the sequence, especially the lower part, seems to favor closer affinity with the upper Pierre. Sandy and carbonaceous phases of the upper Pierre are common in western and central Montana, central Wyoming and in eastern Wyoming in the Lance Creek area. A similar lithology is also recorded for the upper Pierre in the log of the deep test well, referred to above, on Rawhide Creek, eighteen miles north of Corn Creek in Goshen Hole. With the data at hand it seems that the most logical correlation, therefore, is to refer the dark carbonaceous sandy shales along Corn Creek to the upper Pierre, possibly to include part, at least, of the Pierre-Fox Hills transitional phase.

The yellow, brown, red and greenish-gray sands, sandstones and shales in Goshen Hole may be unequivocally referred to the Lance. Ceratopsian remains occur from a few feet above the Pierre throughout the series in the Corn Creek vicinity. The exact relationship between this series and that in the Horse Creek vicinity cannot be accurately determined. The Lance continues under the coal bearing beds on Horse Creek as is indicated in shallow water wells. Since the brackish water beds are not present in the Corn Creek vicinity perhaps they are stratigraphically higher. In this event, the total thickness of the Lance would be about 375 feet or more. On the other hand, the outcrops on Horse Creek may represent the westernmost extent of the brackish water deposits which may really be synchronous in disposition with some part of the series at Corn Creek. This relationship can be estimated only by subsurface work on Horse Creek to determine the underground thickness of the Lance.

The normal thickness for the Lance in other areas is 700 feet or more. Its thinness in Goshen Hole may be explained by the fact that local uplift after Fox Hills times, as is indicated by the absence at Corn Creek of the typical members of that formation, developed the area into a structural high so that no thick accumulation of Lance could follow. Since the uppermost Lance is represented in the area by the Torrington member, the thinness of the formation cannot have been caused by surface erosion. The general sequence, then, of the Lance is a lower series of continental deposits 100 to 200 feet in thickness which contain ceratopsian and other dinosaur remains; 80 to 125 feet of brackish-water deposits (see palaeontology section of this paper for complete list of invertebrate fossils); and an uppermost continental series 60 to 100 feet in thickness which the author has named the Torrington member and which contains an advanced form of *Triceratops*.

The lower part of this sequence certainly may be correlated with the ceratopsian beds of the Lance formation in other areas such as Lance Creek, Wyoming, the Dakotas, eastern Montana, etcetera. While the overlying brackish-water beds were being deposited, marine conditions must have existed to the east or northeast. The only known record of such conditions is the presence in western North and South Dakota of the Cannonball Marine member of the Lance (Lloyd 1914, Lloyd and Hares 1915). This marine member is above the *Triceratops* beds and thins rapidly toward the west grading into the Ludlow lignitic member (Lloyd and Hares 1915, p. 539), and near Yule in Billings County, North Dakota, just east of the Montana state line, oyster beds occur which are considered by Stanton (1920, p. 9) to represent a deposit in "a brackish-water estuary or inlet at the western margin of the Cannonball sea." On the basis of the available information, a tentative correlation of the brackish-water deposits in Goshen Hole with some phase of the Cannonball seems allowable.

No ceratopsians were found above the Cannonball member. Calvert (1912, p. 471), however, states that in eastern Montana ceratopsian bones were found in beds which are supposed to be stratigraphically higher than the Cannonball. Further detailed investigation of the upper Lance in this area, as well as in others, may bring to light evidence of the occurrence of a series of beds comparable to the Torrington, with advanced forms of *Triceratops*, showing that that member of the Lance is of considerable geographic extent.

That the Torrington member is equivalent to at least part of the Arapahoe-Denver beds in the Denver Basin is indicated by the close affinity of the ceratopsians found in both. This is additional evidence for considering the Torrington as an upper-most member of the Lance.

STRUCTURE

Since the structural geology of Goshen Hole will be considered at length in the last of this series of contributions, the present paper needs only to include a treatment of the subject insofar as it directly concerns the development of the Cretaceous.

The structural conditions illustrated in Goshen Hole are doming, arching, folding, fracturing and minor faulting with major faulting to the northwest. On the Laramie River, a few miles west of the town of old Fort Laramie there is present a major normal fault with a strike E. 20°N. and dipping 61°S., accompanied by much minor faulting (found by the author and later to be described in detail in this series). Paralleling the strike of this major zone of fracture is a vast system of minor faults and fissures throughout the Goshen Hole area. The major structural feature is a broad up-warping or doming of the whole region. This condition is made particularly evident by the attitude of the strata exposed along the escarpment which almost completely encircles the region. Everywhere along this prominent topographic feature the beds dip, with a magnitude of from one to three degrees, away from the interior lowlands.

The most important structural feature in Goshen Hole is an anticline which lies in the vicinity of Corn Creek between Y.B.O. Pass and the town of Yoder. I wish to designate this structure as the Corn Creek Anticline. It has a northeast-southwest strike and the length of its exposed surface is approximately ten miles. At Y.B.O. Pass it plunges under the escarpment with an inclination of from one to three degrees. Rising to the northeast, it appears to assume its maximum height and its maximum northwest-southeast arching just to the south of Red-Bill Point on Corn Creek, and then plunges to the northeast under the Tertiary about two miles west of the town of Yoder.

It may be estimated from the discussion of the stratigraphy above that there is a dip to the northwest of at least four hundred and fifty feet in less than four miles from Corn Creek to the Red-Bill Point vicinity. This dip continues fairly uniformly from Red-Bill Point northwestward for several miles and then becomes increasingly greater, nearer the zone of the large fault west of old Fort Laramie where a seven to eight degree dip is very apparent in the Tertiary strata. Southeastward from Corn Creek the dip is more gentle,—about one degree. If the *Trachodon* beds near Fox Creek Gap can be correlated with those along Horse Creek, then the Torrington member is present in that locality, which may mean the presence there of the full thickness of the Lance as represented in Goshen Hole. There is the possibility, however, that these beds, in spite of the similarity to the Torrington member both in lithology and in the presence of *Trachodon* fragments, may represent a level in the typical ceratopsian member of the Lance in which, in areas outside the one under consideration, *Trachodon* remains occurs abundantly. In such an event the Lance would be thin, and since the surface elevation is two hundred and eighty feet above the elevation of the Pierre-Fox Hills on Corn Creek this would indicate an arching in the Fox Creek Gap vicinity. Moreover, if the *Trachodon* beds belong to the Torrington there is also evidence of structure, for subtracting the full thickness of the Lance (375±) from the surface elevation the top of the Pierre-Fox Hills would be 150 to 200 feet higher than at the Red-Bill locality. The structure would not, however, be as pronounced as that at Corn Creek. Whether or not the typical Fox Hills is present can be determined only by subsurface work. In addition, the escarpment between Big Lone Tree Creek and Fox Creek Gap presents a southwest dip of at least one degree, and Tertiary sediments are present at a much lower elevation between this vicinity and that of Corn Creek. This arching includes a surface area southeastward as far as the Hawk Springs Reservoir and northeastward almost to the town of Huntley. Because of the lack of good exposures and because of the unconsolidated nature of the sediments, accurate measurement of dips is for the most part impossible. Local faulting, mentioned above, with measurable dips as great as four degrees are very apparent on Horse Creek several hundred feet north of the coal mine.

PALAEONTOLOGY

Invertebrates

I am indebted to Dr. John B. Reeside, Jr., of the United States Geological Survey, for his identification of the invertebrate collections from the Lance. His list of species and the localities from which they were collected is as follows:

N. W.¼, Sec. 19, T. 23N., R. 61W.

Ostrea glabra Meek and Hayden
Anomia micronema Meek
Corbicula cardiniaeformis White
Corbicula planumbona Meek
Corbicula sp.

SW¼, Sec. 13, T. 22N., R. 61W.

Ostrea glabra Meek and Hayden
Melania wyomingensis (Meek)

SW¼, Sec. 10, T. 22N., R. 61W.

Membranipora sp. unnamed
Anomia ? sp.
Corbula subtrigonalis Meek and Hayden
Small *Planorbis*-like gastropods, undetermined
Cyprid ostracods, undetermined

NE¼, Sec. 15, T. 22N., R. 61W.

Ostrea glabra Meek and Hayden
Anomia micronema Meek
Corbicula planumbona Meek
Corbicula augheyi White
Corbicula sp. undetermined, internal molds only

In commenting on this fauna Dr. Reeside[1] says, "All of the lots represent a brackish-water fauna. There are no strictly fresh-water shells and no typically marine shells. All of the species occur in the Laramie formation of the Denver Basin, and most of them have been recorded from the lower Lance formation. By themselves they do not indicate an extension of the Cannonball sea into southeastern Wyoming, though they do indicate the presence somewhere near by of truly marine waters." To recapitulate what I have stated previously in this paper, the brackish-water deposit which indicates near by marine conditions is above beds containing *Triceratops* and *Trachodon* remains. The only other recorded marine-brackish water deposits of similar stratigraphic position in the Lance is the Cannonball marine member. Perhaps the brackish-water deposit in Goshen Hole represents a different phase of the Cannonball, or a tongue of that sea which is somewhat earlier than the one represented in North and South Dakota. However, that the two are nearly equivalent in time as stated previously, is strongly suggested by the high stratigraphic position of the conformably overlying continental beds containing the very advanced form of *Triceratops*. Only from additional evidence procured by extensive field work in the Lance throughout the Great Plains area with particular attention given to its upper members can this problem of correlation be solved.

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[1] Communication by letter.

VERTEBRATES

Vertebrate remains are abundant. Isolated vertebra and scutes of a small crocodilian were collected, which, according to Dr. C. C. Mook[1], probably belong to the genus *Leidyosuchus*. Fragments of large Chelonians are not of unusual occurrence, and *Trachodon* bones are numerous. None of the discovered remains, however, were sufficiently complete to permit specific determinations. Ceratopsians abound. The skull and jaws and some skeletal parts of a new *Triceratops* were collected. The following is a study of this rare and important specimen.

Class	Reptilia
Subclass	Diapsida
Superorder	Archosauria
Order	Orinthischia
Suborder	Ceratopsia
Family	Ceratopsidae

TRICERATOPS EURYCEPHALUS [2] sp. nov.

Type. M. C. Z. No. 1102. Nearly complete skull and jaws and parts of skeleton. Discovered 1930 by E. M. Schlaikjer and collected in 1931.

Horizon and locality. Upper Cretaceous. Torrington member of the Lance formation, Goshen County, Wyoming.

Specific Characters. 1. Crest greatly expanded in proportion to the length of the skull. 2. Facial region abbreviated and broadly triangular in outline when seen from above. 3. Orbit elevated so that almost two-thirds of its area is above the posterior of the nasal. 4. Antero-inferior corner of the squamosal extended forward, giving a straight anterior border to the squamosal. 5. Dentary short and proportionately deep with high coronoid which distally is little antero-posteriorly expanded. 6. Brow-horns proportionately very long and relatively slender. 7. Nasal horn greatly diminished. 8. Olfactory nerves separate and diverge laterally immediately in front of the cerebrum. (See plates IV and V.)

Description. None of the rostrum is preserved. The presence of a complete nasal and jaws has permitted, however, a fairly accurate restoration. As is indicated by the facial proportions and by the width of the predentary, it must have been wide and massive. The right nasal is missing but the left is completely preserved. It is slightly vascular, especially along the posterior of the narial margin. The dorsal surface is gently concave antero-posteriorly. Posteriorly the nasal is broad and anteriorly it converges rather rapidly. The nasal horn base is represented by a small, low, vascular, oval-shaped, rugose prominence which faces obliquely upward. It is more probable that in life this prominence bore a pad-like protuberance, rather than a true horn. Only a fragment of the left maxillary was found. It presents deep alveoli, and externally a rather prominent facial ridge is present. The orbit is elliptical in outline and is inclined with the inferior border slightly forward. It occupies an elevated position in the skull so that almost two-thirds of its area is above the level of the posterior of the nasal.

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[1] Verbal communication.

[2] From the Greek, *euros*, wide, and *cephalos*, head.

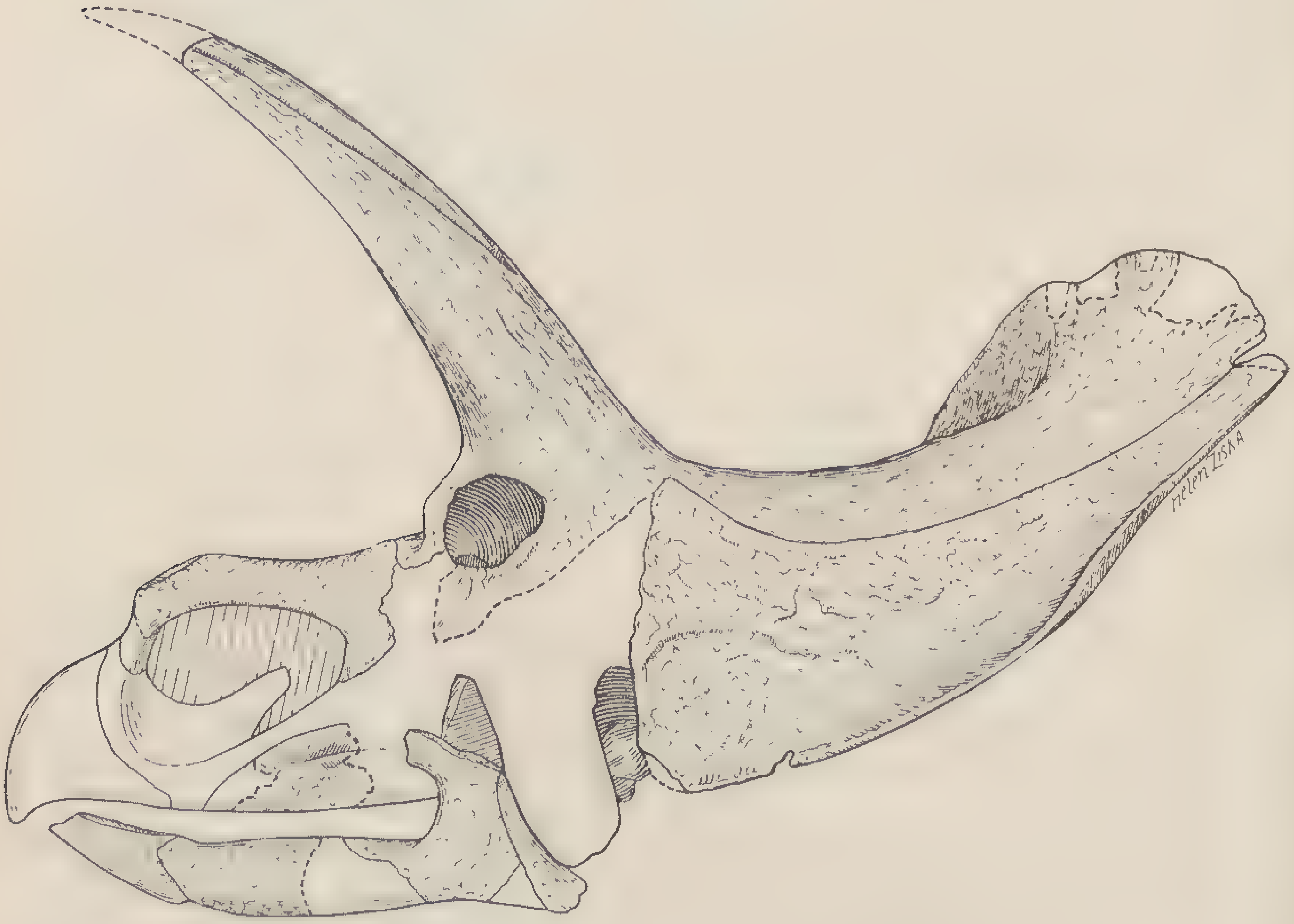

FIG. 3. *Triceratops eurycephalus.* Lateral view of the skull. One-fourteenth natural size.

The jugal (see Plate 5) is proportionately fairly short and broad. Its position is nearly vertical as seen from the side view, but distally it is sharply deflected out away from the skull. A low keel is present externally on the lower one-third and is located about two-thirds of the way back. The sides are nearly parallel,— tapering only gradually and about three-fourths of the way down they begin to converge rapidly and come to a blunt point distally. No epijugal is preserved but one probably was present.

The distal ends of the postorbital horn cores are missing but the left is more complete than the right. Proximally they are oval in cross-section,— being much broader behind than in front and becoming more circular distally. They extend obliquely upward from the skull, curving outward and forward, and near the tips slightly inward. Their posterior surfaces are more deeply vascular than are their lateral or anterior surfaces. They are proportionately longer and more slender than in any other species. In general form they are close to the horns of *T. alticornis*, from the Denver formation. Another horn (U. S. N. M. No. 7086) in the National Museum collection from the same formation is almost identical with that of *T. eurycephalus*, although it must be remembered that accurate specific determinations and affinities cannot be based on brow horns alone.

Perhaps the most unusual single feature of the entire skull is the great width of the crest in proportion to the length (see Plate 5). This exceptional widening appears to be in no way the result of crushing for the symmetry of the parietals and squamosals seem to be little disturbed. The squamosal is proportionately wide and is plow-share-like in general form. The antero-inferior edge is extended more anteriorly than in any other species of Triceratops. The anterior edge is, therefore, practically straight and as a result, the infratemporal fossa is restricted. The lateral edge is smooth and comes to a thin margin with no indication of the presence of epioccipitals. The distal end of the squamosal is blunt, however, and an epioccipital may have been present there. Vascular impressions are well developed in the dorso-marginal anterior area, with few elsewhere on the dorsal and inferior surfaces. The parietals are completely fused, and are proportionately very broad. They are gently arched transversely and posteriorly they are flattened and curve upward rather sharply. Not all of the antero-lateral portions are preserved, but they are sufficiently complete to indicate that no parietal fenestra were present. The median ridge is only slightly undulatory and the posterior margin is developed into a smooth thin edge with no indication of epioccipitals. Vascular impressions are neither abundant nor well developed and there are no special zones of these impressions.

In the basi-cranial area only the occipital condyle with parts of the ex-occipitals, the left orbitosphenoid (alisphenoid) and the left pterygoid are preserved. The occipital condyle is nearly circular in outline and is proportionately unusually small. It is only 6.6 centimeters in diameter. The pterygoid is short and unusually massive. The basioccipital wing and the ridge immediately in front of it are nearly parallel and they are low and especially heavy.

The left orbitosphenoid (alisphenoid) is splendidly preserved. It is in no way distorted and it presents excellent articulatory surfaces. The ascending wing is fairly long and narrow, and distally its blunt oval termination fits into a socket in the postorbital under the center of the brow-horn base. The orbitosphenoid was not coossified with any of the surrounding bones. Antero-posteriorly it is proportionately long. Posteriorly it terminates just at the anterior of the fifth nerve foramen, above which is the proötic surface, and below which is the surface for the basisphenoid.

The orbitosphenoid contains all of the brain cavity in front of the fifth nerve, and from this cavity it was possible to get a splendid cast of that region of the brain (see Fig. 5). In size, the brain is a little more than two-thirds that of *Triceratops serratus* (Hatcher 1907, p. 39, Hay 1909, pl. 9) or *Triceratops* sp. U. S. N. M. 5740 (Gilmore 1919, p. 103). The post-cerebral constriction seems more pronounced in *T. eurycephalus* and cranial nerve III is not immediately behind II and inferior to IV, as it is in *T. serratus,* but is more behind IV. The most outstanding feature of the brain, as preserved, is, however, the separation and rapid lateral divergence of the olfactory nerves immediately in front of the cerebrum. This condition probably is directly coincident with the shortened facial region of the skull. A supero-mesial ridge in front of the cerebrum indicates perhaps that a well developed partition was present between the olfactory stalks.

In general outline, the jaws are bluntly triangular — being proportionately far apart posteriorly. The articulars, angulars, and sphenials are missing. A small part of the anterior end of the right dentary is broken away but this is preserved on the left and there can be no question about the length of the jaws. The dentary is unusually short and is proportionately deep (see plate 4). The coronoid is high and the distal end faces upward and forward and is only slightly expanded antero-posteriorly. Viewed from in front, it is set considerably external to the tooth row. No teeth are preserved, but in the right dentary twenty-two alveoli are present. As stated above, the front of the right dentary is broken away but, as indicated by the left, not more than one alveolus is missing. The posterior end of alveolar portion of the dentary is also missing but certainly not more than two or three alveoli have been lost. The total number of alveoli, therefore, may be conservatively estimated as twenty-five or certainly not more than twenty-six. The predentary is relatively long, flat and massive.

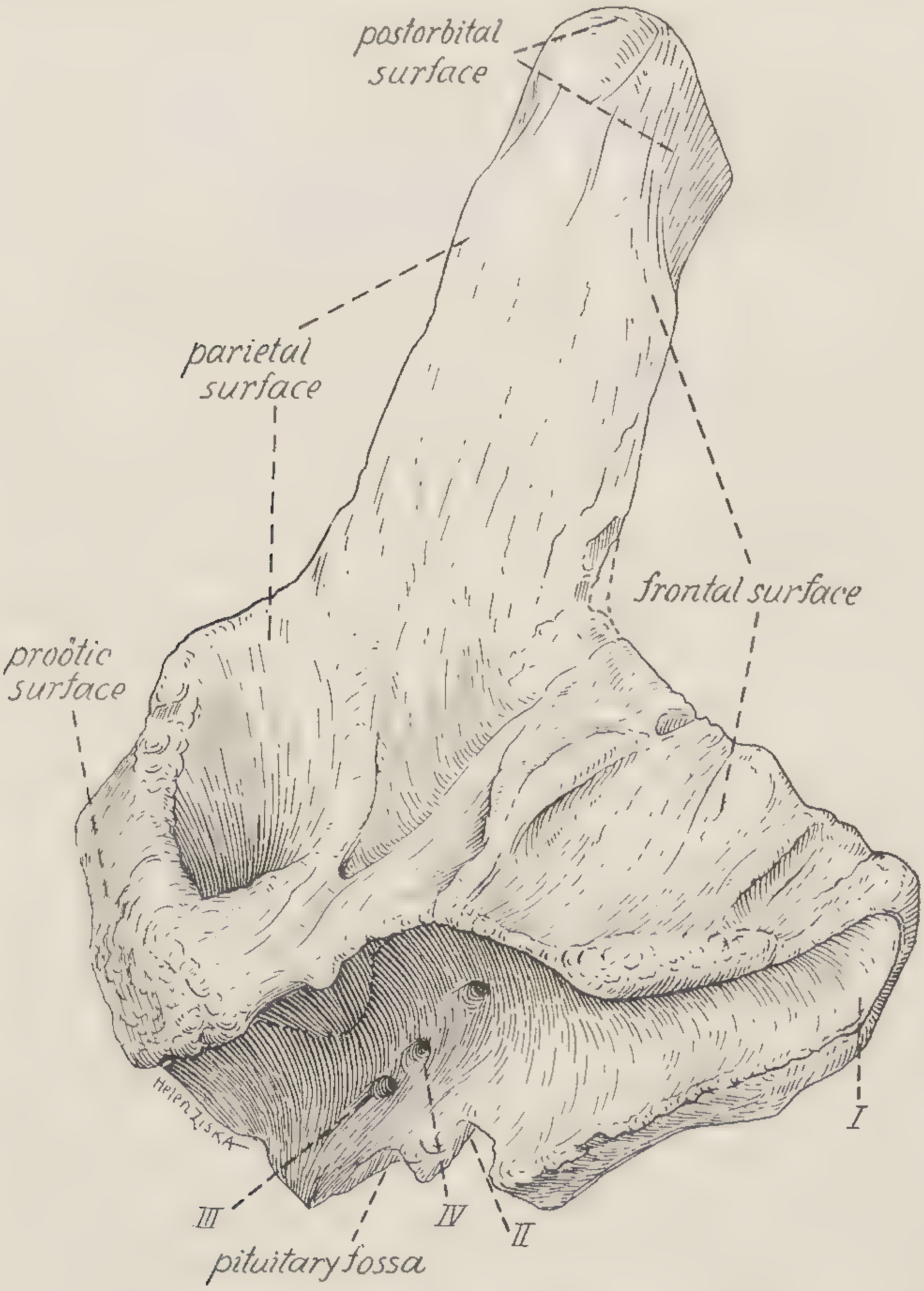
postorbital surface
parietal surface
frontal surface
proötic surface
Helen Ziska
I
III
IV
II
pituitary fossa

FIG. 4. *Triceratops eurycephalus.* Antero-internal view of the left orbitosphenoid (alisphenoid) bone. Two-thirds natural size.

A number of skeletal parts are preserved but the skeleton of *Triceratops* is not as yet sufficiently known to enable one to make specific determinations. It is of interest to note, however, that the right femur of *T. eurycephalus* is practically as long as the femur of the large *T. elatus* (?) skeleton in the American Museum, but it is by far less massive. The scapula, coracoid and other parts of the skeleton such as vertebra, ribs and fragments of the distal limb elements indicate the same condition. From this it can be concluded that in stature *T. eurycephalus* was almost as large as any of its Lance relatives but was indeed a more slender-bodied and perhaps a more agile form.

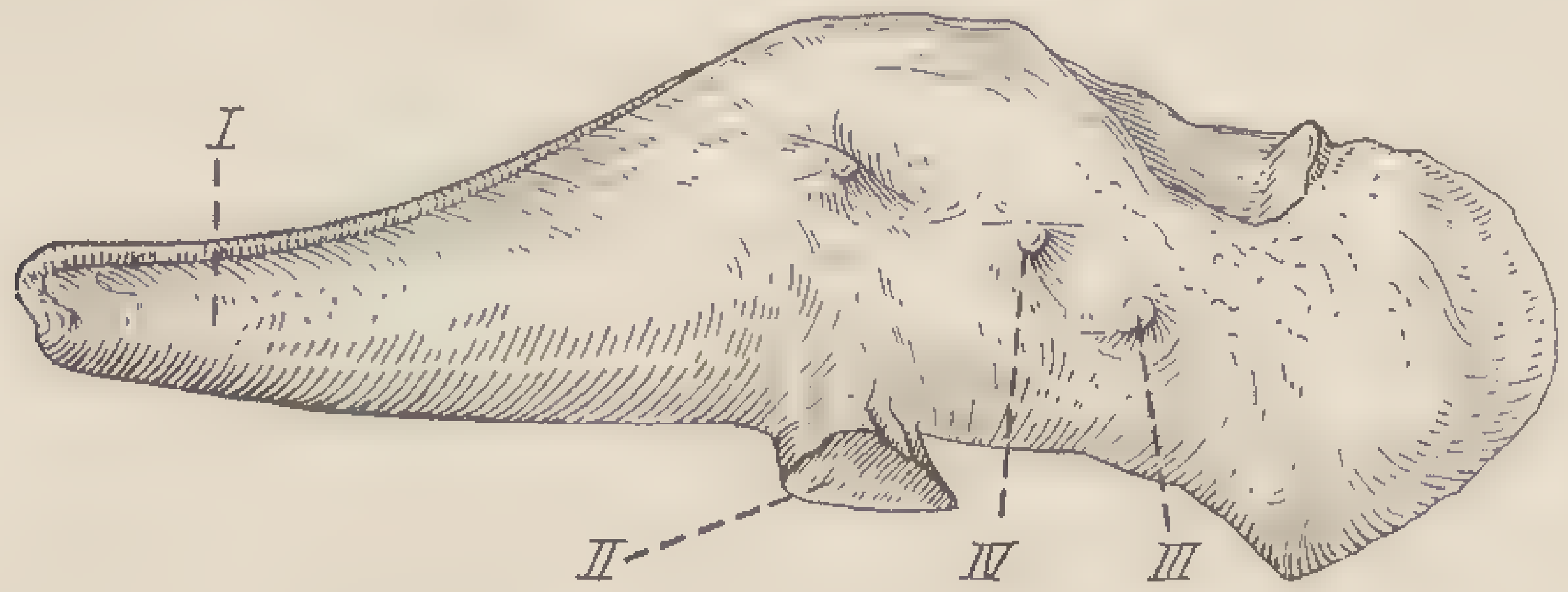

Fig. 5. *Triceratops eurycephalus.* Left view of the cerebral region of the brain. Two-thirds actual size.

Measurements	cm.
Length of skull	138.6
Greatest breadth of frill	129.7
Jugal from inferior or orbit to distal end	32.6
Width of jugal just above distal tapering	11.7
Expanse of frontal region at anterior border of orbits	34.0
Greatest diameter or orbit	12.7
Least diameter of orbit	10.0
Antero-posterior diameter of horn core 6″ above orbit	13.4
Transverse diameter of horn core 6″ above orbit	10.8
Distance from mid-frontal region to apex of supra-orbital horn (as preserved)	62.8
Antero-posterior diameter of nasal horn prominence	5.2
Greatest width of squamosal	35.0
Diameter of occipital condyle	6.6
Length of predentary	22.0
Combined length of dentary and predentary	57.4
Length of anterior of predentary to posterior of surangular	65.5
Length of tooth row (estimated)	32.0
Height of coronoid above bottom of jaw	21.9
Distal antero-posterior expansion of coronoid	6.9
Depth of jaw immediately in front of coronoid	11.2

Discussion and phylogeny. When it is remembered that not more than twenty-five skulls of *Triceratops,* which are specifically determinable, have been collected from a formation, the Lance, representing a duration of time of about five million years and which is represented by abundant out-crops geographically distributed over a vast area from Saskatchewan and Alberta to Mexico, it is not difficult to understand why the determination of the relationships among the various species of *Triceratops* is such a difficult problem. It is fortunate, however, that a single locality (Niobrara County, Wyoming) has provided all of the type material of the nine valid species thus far described. It is also fortunate that all of the types with the exception of *T. serratus* were collected by that great naturalist and collector J. B. Hatcher whose accurate field work included a record of the strategraphic position in the Lance of every specimen obtained by him. This information has been very valuable in the study of phylogeny of the various species.

The question of the relation of *T. eurycephalus* to the other species of *Triceratops* is of unusual importance not only because this species represents the culminative stages of definite evolutionary trends in *Triceratops* during Lance times, but because it is intermediate between certain other species and thereby contributes to a better understanding of the relation of the different lines of development in this genus.

Perhaps the most outstanding single feature of *T. eurycephalus* is the great breadth of the crest in proportion to the length of the skull. Anthropologists have long used the terms brachycephalic (short-headed), mesaticephalic (middle-headed) and dolichocephalic (long-headed) to define the cranial proportions of the human skull. These proportions are obtained by dividing the width of the cranium by the length and the result is termed a cephalic "index." This terminology was first introduced in the study of fossil mammals by Professor Osborn in 1900 and in this connection has been most elaborately used in his monumental work on the titanotheres (1929). Widening of the mammal skull is mostly the result of lateral growth of the zygomata while the cranial region itself may remain proportionately dolichocephalic. In *Triceratops* the widening of the crest is not exactly homologous to brachycephaly in certain mammal skulls. It is, rather, an actual enhanced transverse growth of two important cranial elements, the parietal and squamosal; a transverse growth irrespective of antorbital-postorbital skull length proportions. This is admirably illustrated by the skulls of *Protoceratops* in the splendid collection at the American Museum. For example, by comparing two skulls, one a fairly young individual (No. 6408) and a second which is an adult (6414), it is shown that there is an actual lengthening of 106 mm. in the antorbital region and 103 mm. in the postorbital region while there is an actual increase of width in the crest of 260 mm., or more than the actual increase of the skull's length.

Among the species of *Triceratops* the same condition is present. For example, the antorbital region of *T. hatcheri* is proportionately longer than it is in *T. brevicornus,* yet the crest of *T. hatcheri* is proportionately much wider. Moreover, the proportion of the antorbital region in *T. calicornis* is the same as that of *T. brevicornus,* but its crest is proportionately wider than is that of *T. hatcheri.* In other words, as stated above, the crest of *Triceratops* in proportion to the length of the skull becomes wider irrespective of the antorbital-postorbital skull length proportions. Of the known forms this widening of the crest is most emphasized in *T. eurycephalus.* I suggest that this condition be referred to as *eurycephaly* (wide-headedness) in order to avoid confusion with a somewhat different condition among certain mammalian skulls known as brachycephaly (short-headedness). For the forms with narrow crests the term *stenocephalic*[1] (narrow-headed) seems more fitting than dolicocephalic (long-headed). For the intermediate forms *mesaticephalic* (middle-headed) may be used.

In figure six it is shown that the cephalic indices of the *Triceratops* species cover a wide range. *T. flabellatus* presents the lowest index. The low figure for the crest width in this species, however, is probably the result of high arching and of crushing. Its normal index would probably be nearer that of *T. serratus.* On the basis of the cephalic indices shown in figure six, I would recommend the following index range for the terms suggested above:

stenocephalic	40 — 65
mesaticephalic	65.1 — 70
eurycephalic	70.1 — 94+

T. prorsus and *T. flabellatus* are stenocephalic. The former, however, is approaching the mesaticephalic stage which includes *T. brevicornus* and *T. serratus.* The eurycephalic species are *T. hatcheri, T. calicornis,* and *T. eurycephalus.* The latter has a crest which is proportionately so much wider than any of the others that it really is

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[1] The terms stenocephalic and eurycephalic have been used by early anthropologists to designate narrow and wide skulls in relation to height. The more accepted terms now in use by anthropologists are akrocephalic (narrow in relation to height) and tapeinocephalic (wide in relation to height). Stenocephalic and eurycephalic are used in this paper to designate narrow or wide skulls irrespective of height.

"hypereurycephalic." In this connection it is of interest to note that those skulls of *Protoceratops,* which can be unequivocally referred to the same species, show that from youth to old age the crest becomes proportionately wider. Since *Triceratops* is not a very distantly related form, it is entirely probable that it, too, possessed this characteristic. If this is true, then *T. eurycephalus,* which according to its open sutures is an immature individual, would have been even more eurycephalic had it attained old age. In eurycephaly *T. calicornis* is nearest to *T. eurycephalus,* but only slightly more so than is *T. hatcheri.* In the general form, position and size of the brow horns, however, *T. eurycephalus* seems to be intermediate between these two species. It is definitely nearer to *T. hatcheri* than to any other single species in the following characters.

Species	Age	Skull Length	Crest Width	Index
T eurycephalus	immature	138.6	129.7	93.5+
T. calicornis	not fully adult	210.0	155.2	73.9+
T. elatus	immature	193.4	?	?
T. hatcheri	old	185.4	132.8	71.6+
T. brevicornus	old	165.2	112.0	67.8+
T. serratus	immature	171.0	115.0	67.2+
T. prorsus	aged	152.3	94.4	61.9+
T. flabellatus	very young	187.9	86.4	45.9+
T. horridus	fully grown	?	?	?
T obtusus	old	?	?	?

FIG. 6. Table showing the eurycephalic, mesaticephalic and stenocephalic indices of the *Triceratops* species. Measurements are in centimeters.

1. Reduction of the nasal horn.
2. Slight antero-posterior concavity of the nasal.
3. Structure and form of the jugal.
4. Small number of teeth (*T. hatcheri* has only 24 in the maxillary. *T. eurycephalus* 25–26 in the mandible. No other known form has fewer than 28 and the average number is 30–31).
5. Shape and position of the orbit.
6. Forward extension of the antero-inferior angle of the squamosal.

Because of these affinities, I am inclined to place it phylogenetically (see plate 6) somewhat intermediate between *T. calicornis* and *T. hatcheri*, though closer to the latter. In all of the above mentioned characters *T. brevicornus* ranks third in close relationship to *T. eurycephalus*. This species, however, is much closer to *T. prorsus* which seems to represent a line of *Triceratops* evolution quite apart from the *T. elatus-calicornis-eurycephalus-hatcheri* group throughout Lance times. *T. brevicornus* may be derived directly from *T. prorsus* as Professor Lull has shown in his recent and masterful memoir, "A revision of the Ceratopsia or horned dinosaurs" (1933, p. 28). Professor Lull derives, structurally at least, *T. horridus* from *T. brevicornus*. The former, however, occurs in the lowermost Lance already a large and massive form, removed from the *T. prorsus-brevicornus* line, and which is known to have persisted late in the Lance.

In his tentative phylogenetic chart Professor Lull places, with reservation, *T. obtusus* as the ancestor of *T. hatcheri*. Since *T. obtusus* possesses a number of specializations in the region of the face, the jugal and squamosal, which I believe eliminates it from the ancestry of *T. hatcheri* and in addition, since *T. eurycephalus* by its somewhat intermediate position seems to show a close relationship between *T. hatcheri* and the *T. calicornis-elatus* line, I prefer a phylogenetic arrangement as shown in plate 6. Professor Lull does not include *T. flabellatus* or *T. serratus* in his chart. He rightfully concludes, however, that they are rather far removed from any of the other species, and that their closest affinity is to each other. Nevertheless, in the characters of the nasal, jugal, squamosal and brow horns they seem to be nearest the *T. elatus-calicornis-eurycephalus-hatcheri* group and, tentatively, I suggest their derivation from some early form in that phylogenetic line.

A study of the known *Triceratops* material reveals that several decided evolutionary trends developed throughout each of the diverse specific lines from the beginning of Lance to the closing stage of the Cretaceous. They are as follows:

1. Progressive eurycephaly.
2. Proportionate shortening of antorbital region.
3. Proportionate lengthening of postorbital region.
4. Regressive nasal horn.
5. Progressive development of brow horns.

It is in *T. eurycephalus*, the last known survivor (that is, the last specifically identifiable form; *Agathaumas* and *T. alticornis* may be somewhat later in time) of the ceratopsians, that these concurrent evolutionary trends attain a highly advanced culminative expression.

The ancestry of *Triceratops* is dimmed by the lack of sufficient evidence and is, therefore, a very debatable question. *Brachyceratops,* however, from the Two Medicine formation of the upper Montanan, affords, in nearly all of its skull and skeletal structures, an admirable ancestor. C. W. Gilmore (1917, p. 38) states, however, that "it is hardly conceivable that an animal like *Brachyceratops,* having a nasal horn split longitudinally by suture and an outgrowth from the nasal bones, could be the progenitor of later ceratopsians having this horn developed from a center of ossification distinct from the nasal bones." This seems to be insufficient cause for its elimination, especially when it is remembered that *Brachyceratops* possesses a separate ossicle above the nasal horn which Gilmore himself suggests (p. 9) "may represent the incipient horn of later ceratopsians." A more elaborate discussion of this subject is foreign to the present study.

CONCLUSIONS

1. The dark, carbonaceous, sandy shales exposed along Corn Creek are over a thousand feet in thickness as is shown by core-drilling. These beds are Pierre in age and the upper portion may represent a Pierre-Fox Hills transition.

2. The Lance in Goshen Hole can be separated into three divisions. The lowermost is a continental deposit 100–200 feet in thickness which contains ceratopsian and other reptilian remains. It is therefore equivalent to the *Triceratops*-bearing Lance in other areas. The middle division is a brackish-water deposit 80′–125′ thick which is in a correct stratigraphic position to be correlated with some phase of the Cannonball. Above the brackish-water beds is a 60′–100+′ continental deposit which contains, in its upper portion, a new and very advanced form of *Triceratops.* For this deposit the name, "Torrington member of the Lance" is suggested.

3. Goshen Hole is a topographic basin developed on a structural dome. Within this basin is a pronounced anticline along Corn Creek and a broad low arch in the Horse Creek vicinity.

4. *Triceratops eurycephalus* is a very advanced species and it presents a culmination of the main evolutionary trends in *Triceratops* development during Lance times. Its phylogenetic position is somewhat intermediate between *T. hatcheri* and *T. calicornis* though it is nearer to the former. It aids greatly in determining the phylogeny of all of the *Triceratops* species.

5. *Brachyceratops* of the Two Medicine formation, appears to be the most probable ancestor of *Triceratops.*

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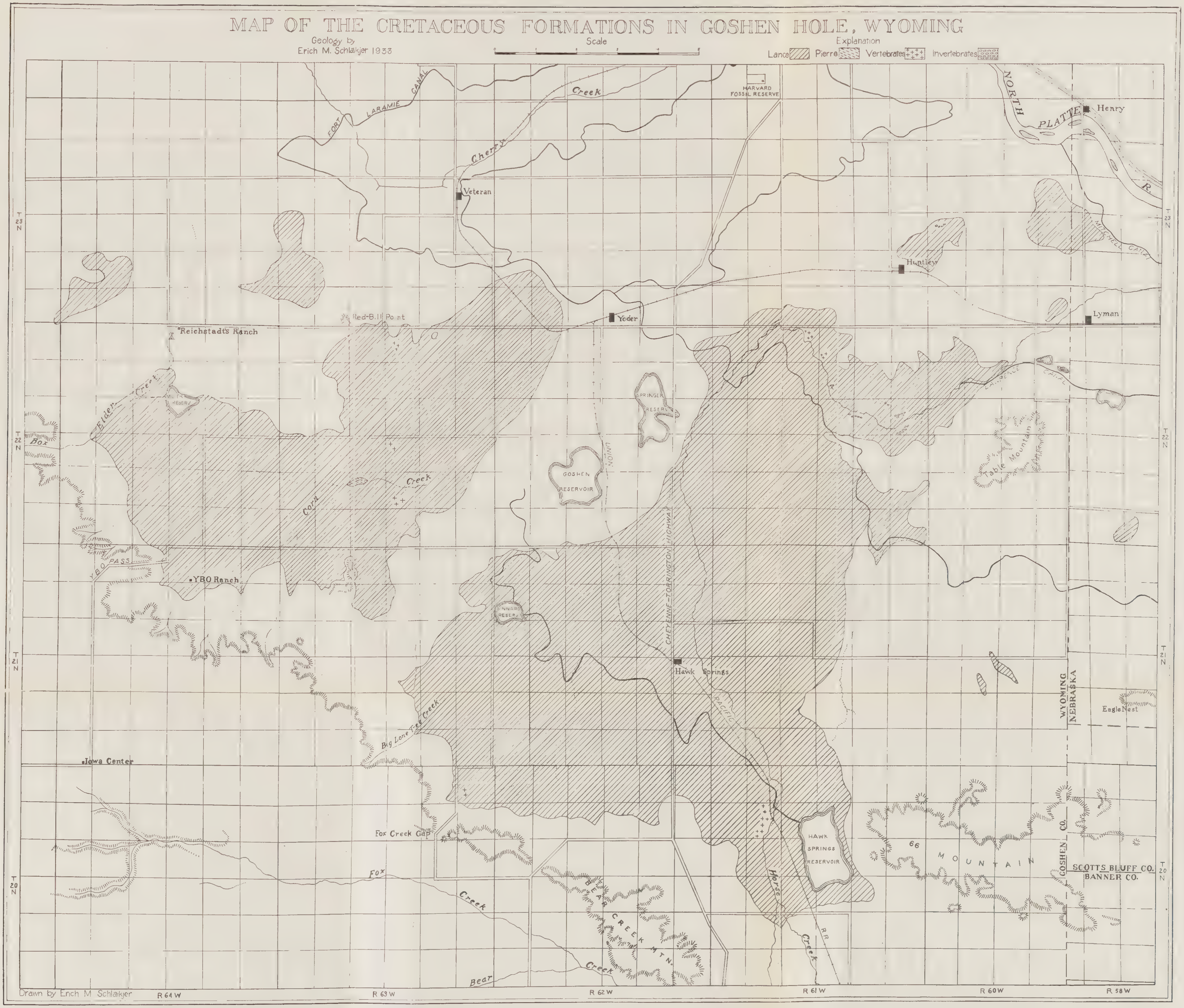
EXPLANATION OF PLATES

PLATE 1

PLATE 1

Map of the Cretaceous formations in Goshen Hole, Wyoming.



MAP OF THE CRETACEOUS FORMATIONS IN GOSHEN HOLE, WYOMING

Geology by
Erich M. Schlaikjer 1933

Scale
0
1
2
3
4
5
Explanation
Lance ▨
Pierre ▨
Vertebrates +
Invertebrates ▨
FORT LARAMIE CANAL
Cherry Creek
HARVARD FOSSIL RESERVE
NORTH PLATTE R.
Henry
Veteran
Huntley
MITCHELL CANAL
Yoder
Lyman
Red-Bill Point
Reichstadt's Ranch
Elder Creek
Box
SPRINGER RESERV.
UNION
GOSHEN RESERVOIR
Cord Creek
CHEYENNE-TORRINGTON HIGHWAY
LAGRANGE CANAL
Table Mountain
YBO PASS
YBO Ranch
Hawk Springs
PACIFIC
Big Lone Tree Creek
WYOMING
NEBRASKA
Eagle Nest
Iowa Center
Fox Creek Gap
Fox Creek
BEAR CREEK MTN.
Bear Creek
Horse Creek
RR
HAWK SPRINGS RESERVOIR
66 MOUNTAIN
GOSHEN CO.
SCOTTS BLUFF CO.
BANNER CO.
T 23 N
T 22 N
T 21 N
T 20 N
R 64 W
R 63 W
R 62 W
R 61 W
R 60 W
R 58 W

Drawn by Erich M. Schlaikjer

PLATE **2**

PLATE 2

1. Typical exposures of the Lance formation along Horse Creek showing local dipping of the beds.

2. Oyster beds along Horse Creek having a measurable thickness of over twenty feet.

1

2

PLATE 3

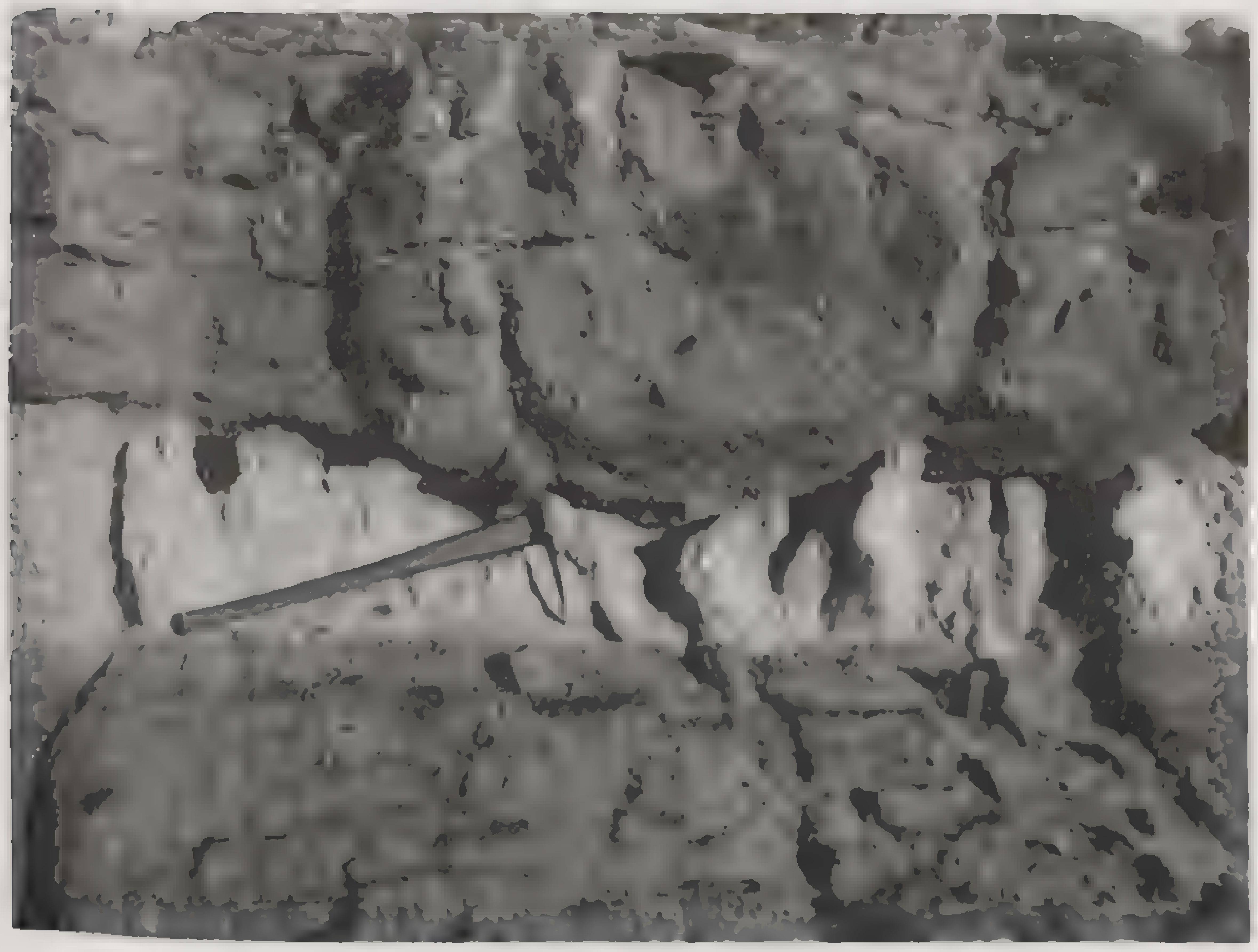
PLATE 3

1. Cannonball concretions in the Lance one mile northeast of Fox Creek Gap.

2. Channel sandstone in the Lance on which rest the lower Oligocene clays One mile northwest of Table Mountain.

Photographs, plates 2 and 3 by Erich M. Schlaikjer

1



2

PLATE 4

PLATE 4

Triceratops eurycephalus Schlaikjer. Skull, right view. Approximately one-twelfth actual size.

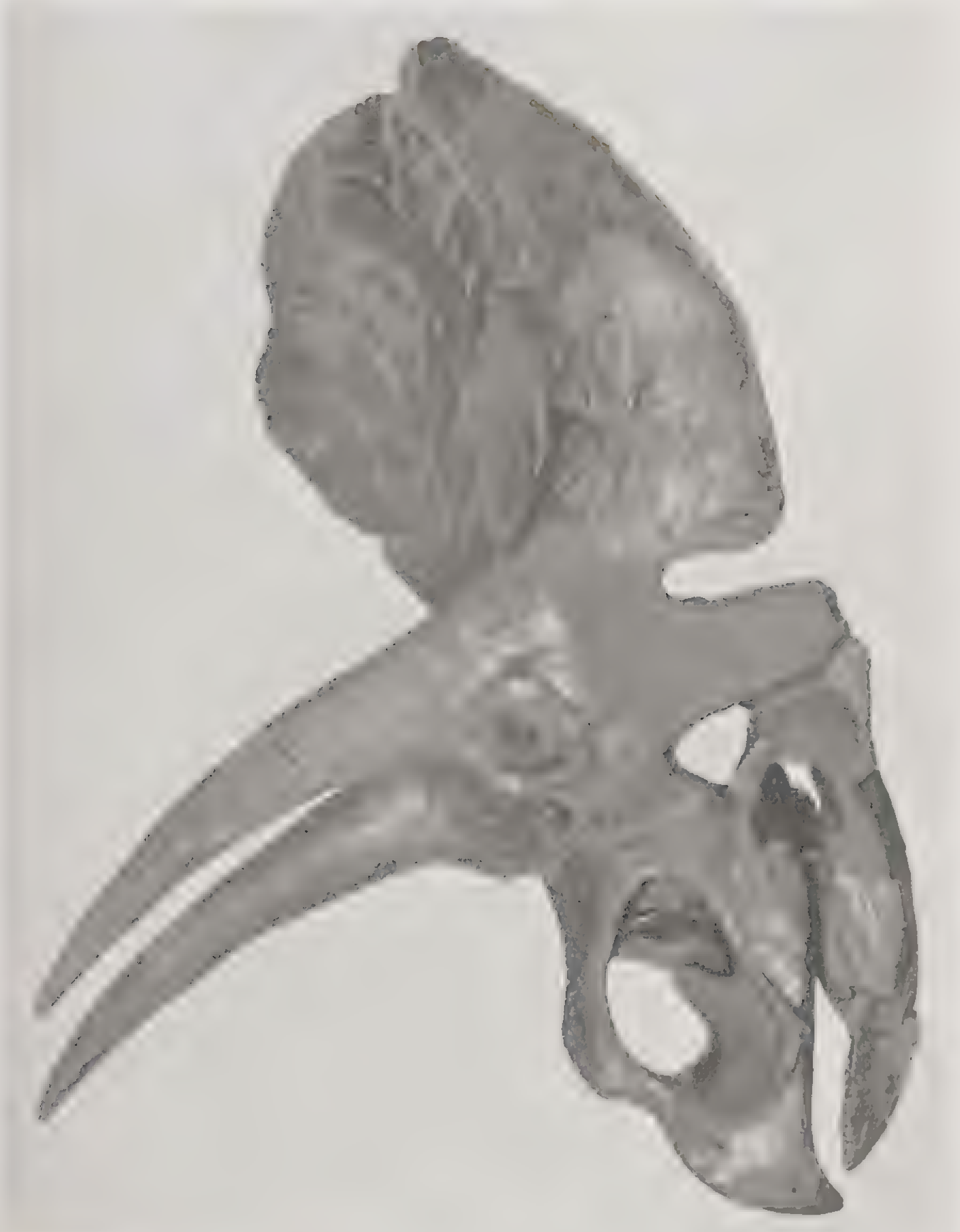


PLATE 5

PLATE 5

Triceratops eurycephalus Schlaikjer. Skull, front view. Approximately one-fourteenth actual size.

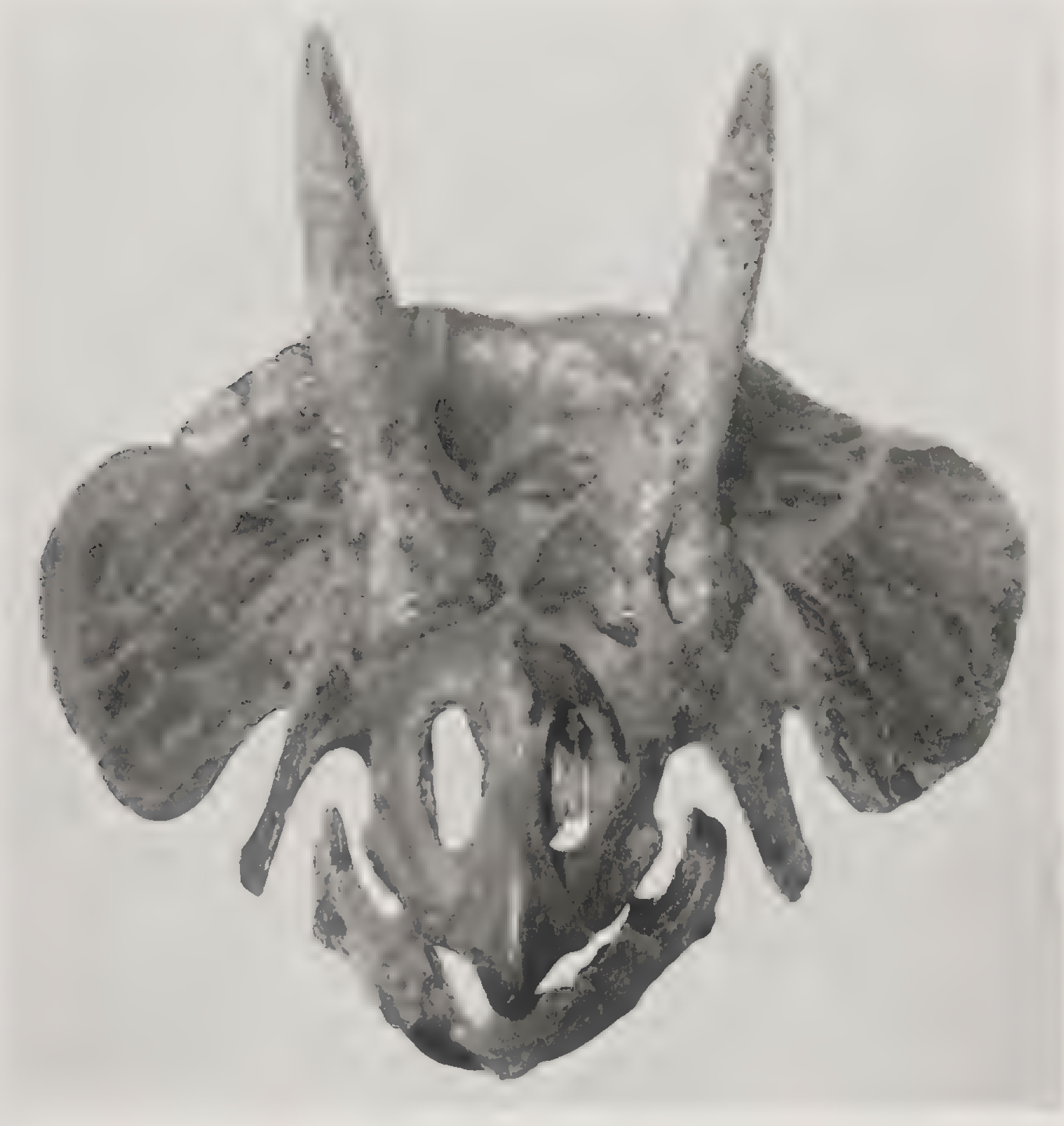
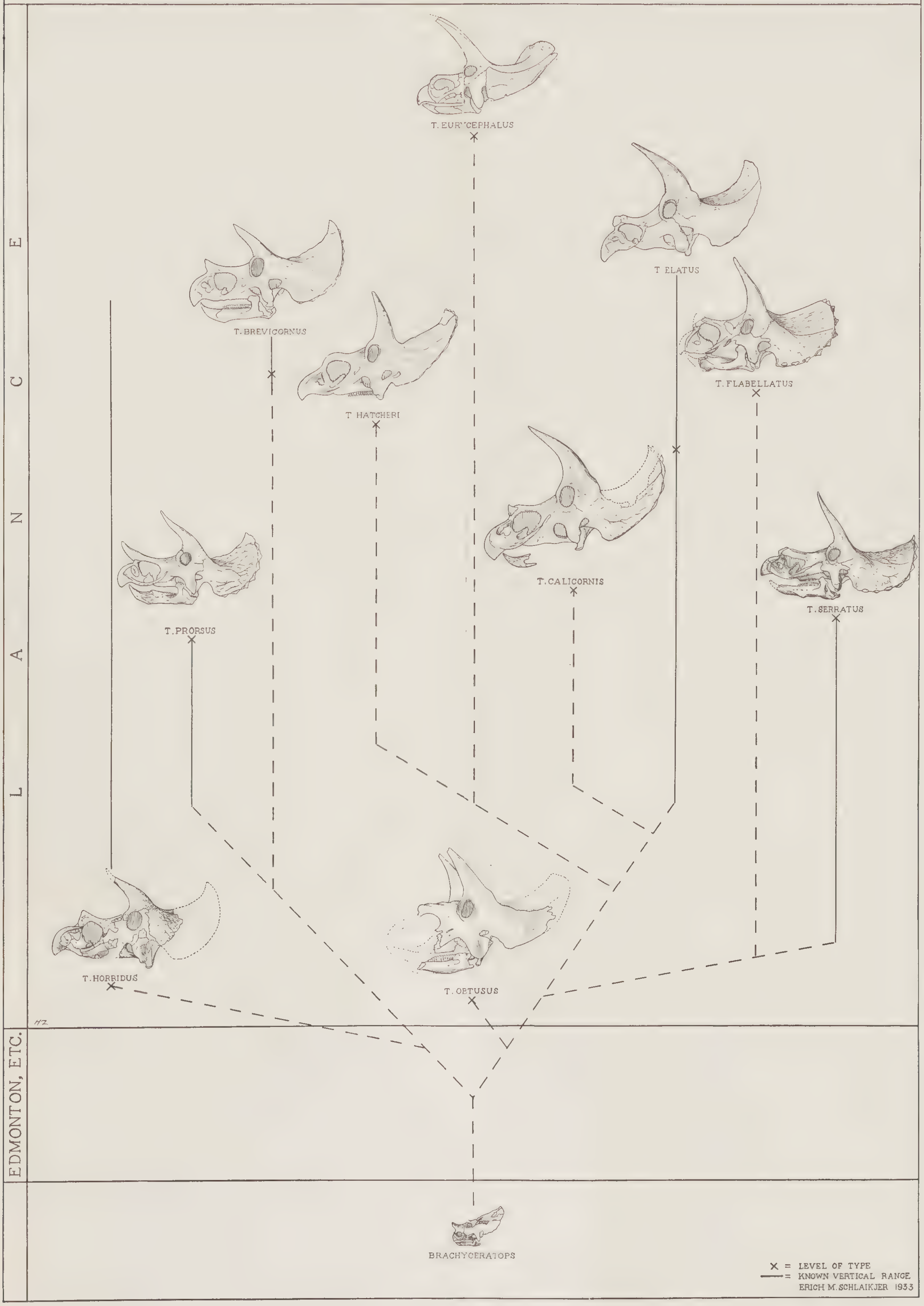


PLATE 6

PLATE 6

Phylogeny of Triceratops. Uppermost Cretaceous, North America.

PHYLOGENY OF TRICERATOPS
UPPERMOST CRETACEOUS, NORTH AMERICA


T. EURYCEPHALUS
T. ELATUS
T. BREVICORNUS
T. FLABELLATUS
T. HATCHERI
T. CALICORNIS
T. PRORSUS
T. SERRATUS
T. HORRIDUS
T. OBTUSUS
BRACHYCERATOPS
LANCE
EDMONTON, ETC.
H.Z.
× = LEVEL OF TYPE
—— = KNOWN VERTICAL RANGE
ERICH M. SCHLAIKJER 1933

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AT HARVARD COLLEGE
Vol. LXXVI, No. 3

3189

CONTRIBUTIONS TO THE STRATIGRAPHY AND PALAEONTOLOGY OF THE GOSHEN HOLE AREA, WYOMING

III

A NEW BASAL OLIGOCENE FORMATION

By Erich M. Schlaikjer

With Eight Plates

CAMBRIDGE, MASS., U. S. A.
PRINTED FOR THE MUSEUM
January, 1935

4H

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No. 3. — *Contributions to the Stratigraphy and Palaeontology of the Goshen Hole Area, Wyoming*

III

A New Basal Oligocene Formation

By Erich M. Schlaikjer

INTRODUCTION

Previous to the publication of a paper by O. A. Peterson and L. J. Kay in 1931 on the Duchesne formation of northeastern Utah, the boundary between the Eocene and Oligocene continental sediments was generally accepted as between the Uinta and the Chadron. The boundary is well defined and was regarded as representing a considerable break, faunistically at least, between these two formations. This marked separation between the Eocene and Oligocene is now less pronounced since the discovery of the Duchesne with its intermediate fauna. The Oligocene affinities of this fauna led Peterson and Kay to consider it as belonging to the basal part of that geological period, while Simpson (1933, pp. 84, 85), because of the occurrence of *Epihippus?* and on the basis of physiographic and stratigraphic evidence places it very tentatively in the Eocene.

In certain parts of the Goshen Hole area, Wyoming, there is a series of fluviatile deposits which lie with unconformity on the Lance formation of the upper Cretaceous and which grade upward into the Chadron formation of the lower Oligocene. This series of beds was first discovered by the author in July 1930 when he began the field research for the Museum of Comparative Zoölogy in that area. During that and subsequent field seasons he has carried out a stratigraphic study of these beds and has obtained from them a considerable collection of vertebrates. A number of the forms represented are new. A description of these together with the results of the stratigraphic investigation is the subject of this paper. From all the available data it seems justifiable to regard these deposits as representing a new formation constituting, in part at least, a transitional stage between the Eocene and Oligocene periods.

I wish to acknowledge the kindness of Mr. Harold J. Cook of Agate, Nebraska who has most generously turned over to me for study and description three specimens which he collected from this formation in the fall of 1932.

The drawings of the specimens in this paper were made by Mrs. H. Ziska.

STRATIGRAPHY

The geographic distribution of this series of sediments is very limited. The combined extent of the exposures in Goshen Hole amounts to not more than five square miles (see Fig. 1). Since the locality is one of low relief no good sections can be measured except along the Fort Laramie irrigation canal, especially one to three miles northwest of the town of Yoder, where deep excavation was necessary to get the canal waters across the plunging northeast limb of the Corn Creek anticline. The walls of this canal present excellent exposures of the beds and a fairly thick section is measurable. The maximum thickness is indeterminable, however, since nowhere is the deepest contact with the Cretaceous observable. The lowermost part of the canal walls is composed of fifteen feet of rather finely bedded fairly coarse red sandstone and dark to red sandy clays. The next eighteen feet is red to greenish sandy clays, and these are over-lain by twenty feet of reddish-green clays with channels of intricately cross-bedded, wine colored coarse gravels to fine sandstone which grade laterally into the clays. Resting on this sequence, in places with no apparent stratigraphic break, are the typical greenish-gray Chadron clays (see Fig. 2). In other places as in Sec. 19, T. 23n. R61w. the series is capped by a greenish-maroon coarse channel sandstone several feet in thickness with the Chadron clays above.

Fossils are abundant and although they frequently occur as fragments they are little if at all water worn. The forms thus far discovered indicate a fauna which is distinctly transitional between the uppermost Eocene, or Duchesne, and the lowermost Oligocene, or lower Chadron. The Eocene representative in this fauna is the creodont, *Miacis,* but it is an end-member of the Eocene forms and may be considered as a living fossil existing along with its more advanced relatives *Hemipsalodon* and *Hyaenodon* at the dawn of Oligocene times. The rhinoceroses and titanotheres are definitely early or pre-Chadron members and the horse, so far as is known is decidedly an intermediate form transitional between *Epihippus intermedius* of the Duchesne and the primitive *Mesohippus* representatives of the early Chadron. The Hypertragulid present is *Leptomeryx* and though it possesses characters more primitive than those found in other species, it is already a typical example of this Oligocene genus. The fauna, therefore, considered in its entirety, seems too progressive to be assigned to the Eocene, yet its primitiveness will not allow it to be regarded as of the Chadron. Because of these facts and because

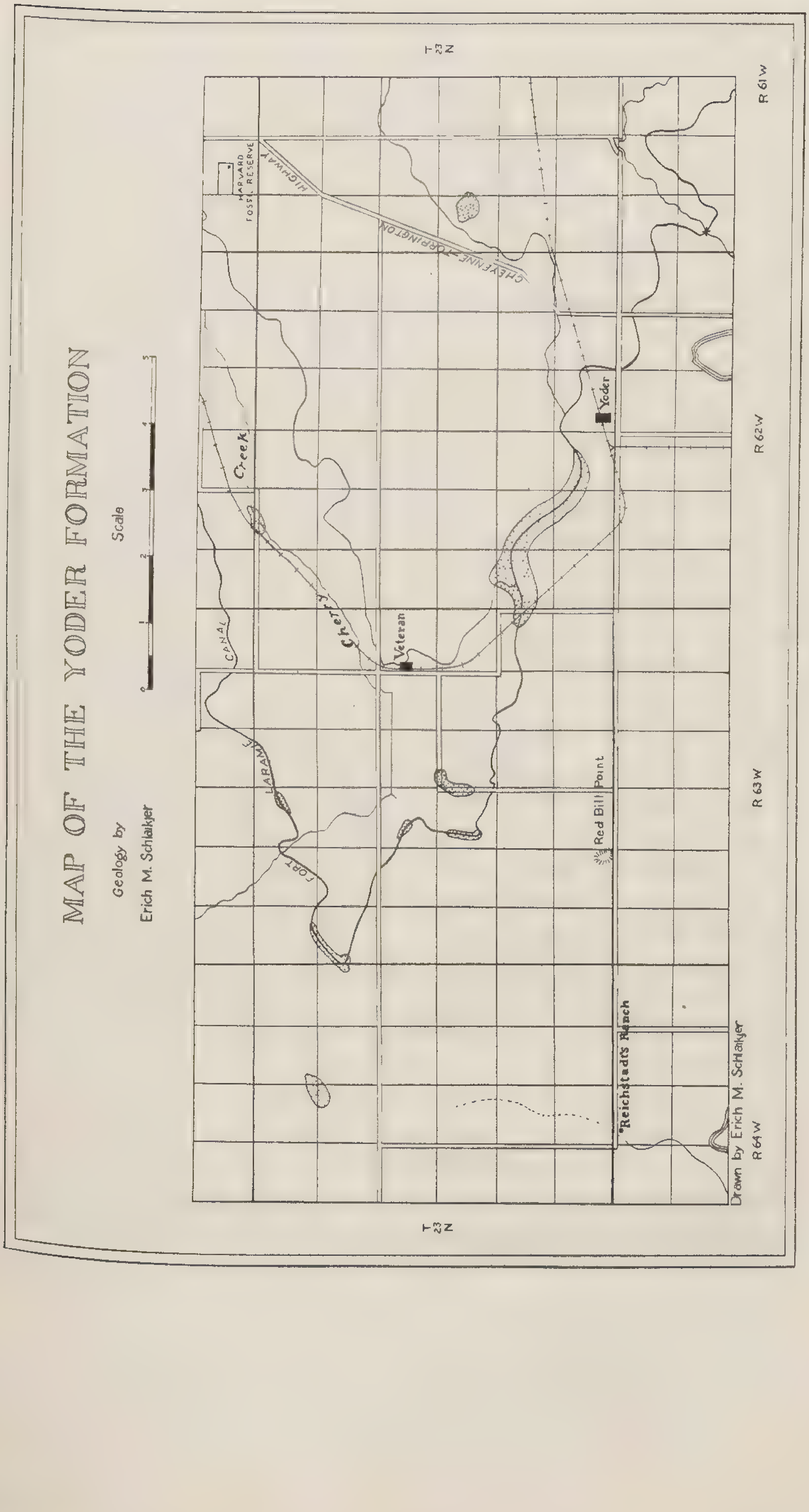
MAP OF THE YODER FORMATION
Geology by
Erich M. Schlaikjer
Scale
0
1
2
3
4
5
T 23 N
T 23 N
R 61 W
R 62 W
R 63 W
R 64 W
HARVARD FOSSIL RESERVE
HIGHWAY
CHEYENNE-TORRINGTON
Creek
Cherry
Veteran
Yoder
CANAL
LARAMIE
FORT
Red Bill Point
Reichstadt's Ranch
Drawn by Erich M. Schlaikjer

FIG. 1

the beds represent a stratigraphic level, quite apart from the upper Eocene and are easily distinguishable from the Chadron, a new formational name is necessary. The name proposed for these deposits is the *Yoder formation,* so named after the town of Yoder which is situated one and one-half miles southeast of the type locality. After an evaluation of the faunal relationships and after its stratigraphic position is taken into account, the Yoder formation should be regarded as belonging to the Oligocene rather than to the Eocene system.

It is a significant fact that the Yoder formation represents the earliest Oligocene deposition, thus far recorded, in the Great Plains region. Nowhere in the Goshen Hole area are Paleocene or Eocene deposits to be found. It is probable however that the former, at least, were present, since Fort Union beds, hundreds of feet in thickness, occur less than eighty miles to the north. Subsequent to Fort Union times and perhaps during most if not all of the Eocene, degradation continued and by the close of the Eocene these sediments as well as some of the Cretaceous had been removed. The beginning of the Oligocene was marked by renewed uplift in the Rocky Mountains which resulted in the rejuvenation of all those eastward flowing streams that then began to carry from the uplands out on to the plains the sediments of the early Oligocene. One of those streams flowed across what is now the Goshen Hole area, entrenched itself in the Lance formation of the Cretaceous and deposited the Yoder sediments. Hence for the first time perhaps since the Paleocene this area became one of deposition. The trend of the Yoder river was from west to east as is admirably shown by the channel deposition. The restriction of the formation to the northern portion of Goshen Hole may be the result of local uplift in the Corn Creek vicinity immediately to the south from which perhaps some of the Yoder sediments were derived. Most of the sediments, however, originated in the nearby Laramie mountain region to the west. The angular condition of the more elastic materials shows that they have not undergone prolonged transportation and the freshness of the feldspars indicates that disintegration rather than decomposition was the major process of erosion at the source.

PALAEONTOLOGY

In the collection of vertebrates from the Yoder there are a few reptilian fragments. These are, isolated fragments of a turtle cara-

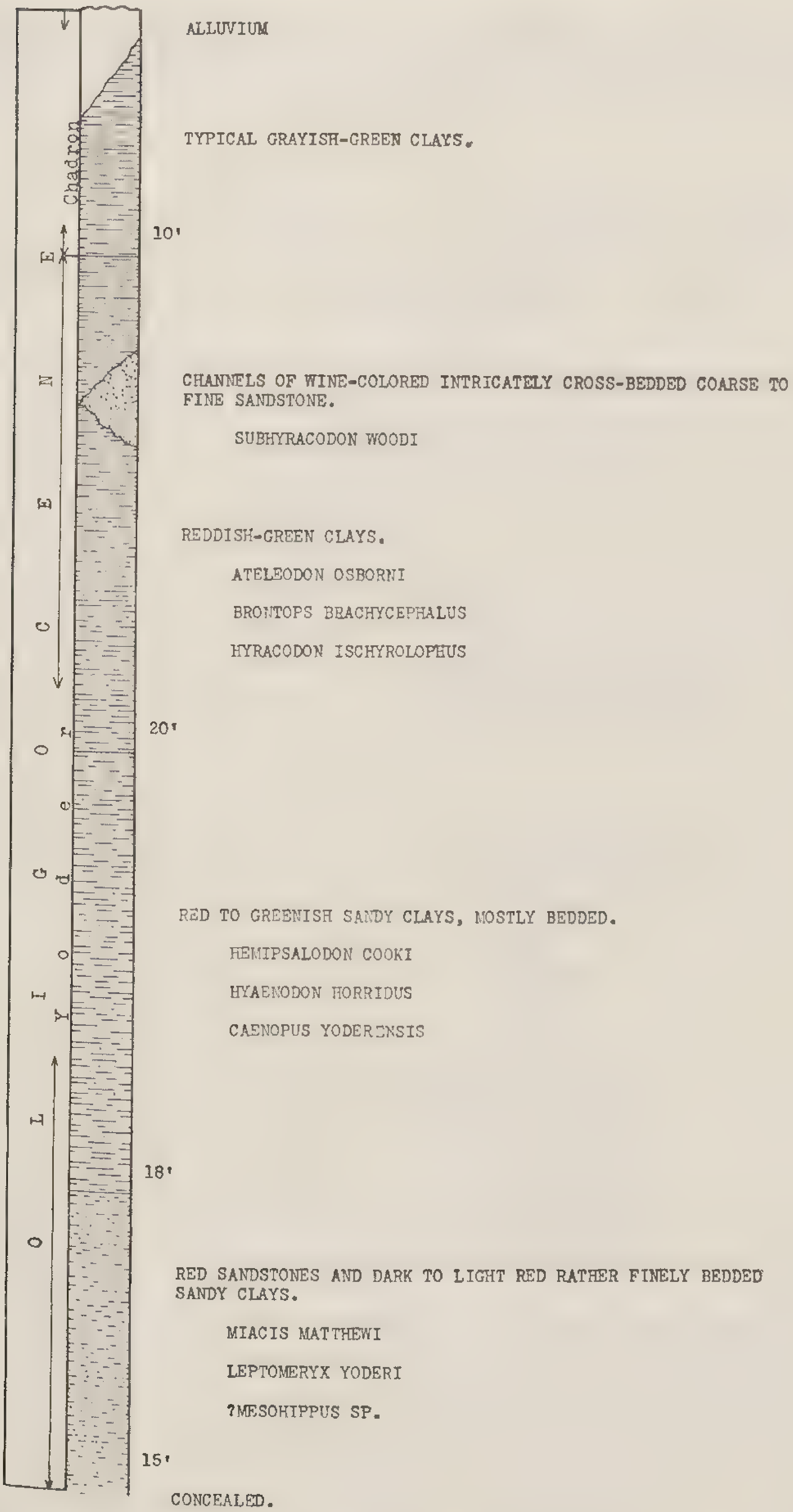
ALLUVIUM
TYPICAL GRAYISH-GREEN CLAYS.
Chadron
10'
CHANNELS OF WINE-COLORED INTRICATELY CROSS-BEDDED COARSE TO FINE SANDSTONE.
SUBHYRACODON WOODI
REDDISH-GREEN CLAYS.
ATELEODON OSBORNI
BRONTOPS BRACHYCEPHALUS
HYRACODON ISCHYROLOPHUS
20'
RED TO GREENISH SANDY CLAYS, MOSTLY BEDDED.
HEMIPSALODON COOKI
HYAENODON HORRIDUS
CAENOPUS YODERENSIS
18'
RED SANDSTONES AND DARK TO LIGHT RED RATHER FINELY BEDDED SANDY CLAYS.
MIACIS MATTHEWI
LEPTOMERYX YODERI
?MESOHIPPUS SP.
15'
CONCEALED.
O L I G O C E N E
Yoder

FIG. 2. Type section of the Yoder formation. S.E. ¼. Sec. 29. T. 23n. R.62w. Goshen Co., Wyoming, E. M. Schlaikjer 1933.

pace and several crocodilian vertebra. None of this material is generically identifiable. The remainder of the material is mammalian of which the following is a faunal list.

Order CARNIVORA
    Suborder CREODONTA
        Superfamily MIACOIDEA
            Family MIACIDAE
                Miacis matthewi sp. nov.
        Superfamily OXYAENOIDEA
            Family HYAENODONTIDAE
                Hemipsalodon cooki sp. nov.
                Hyaenodon horridus Leidy

Order PERISSODACTYLA
        Superfamily EQUOIDEA
            Family EQUIDAE
                ? *Mesohippus* sp.
        Superfamily BRONTOTHERIOIDEA
            Family BRONTOTHERIIDAE
                Ateleodon osborni gen. et. sp. nov.
                Brontops ? brachycephalus (Osborn)
        Superfamily RHINOCEROTOIDEA
            Family HYRACODONTIDAE
                Hyracodon ischyrolophus sp. nov.
            Family RHINOCEROTIDAE
                Caenopus yoderensis sp. nov.
                Subhyracodon woodi sp. nov.

Order ARTIODACTYLA
    Suborder PECORA
        Superfamily TRAGULOIDEA
            Family HYPERTRAGULIDAE
                Leptomeryx yoderi sp. nov.

DESCRIPTION AND DISCUSSION OF NEW MATERIALS

Order CARNIVORA

Suborder CREODONTA

Superfamily MIACOIDEA

Family MIACIDAE

Miacis matthewi[1] sp. nov.

Type. Left lower jaw fragment with M_2 and part of M_1, M. C. Z. No. 2,094 and associated right lower jaw fragment with P_4 and the roots of P_3 and M_1, M. C. Z. No. 2,094a. Collected by E. M. Schlaikjer, 1932.

Horizon and locality. Basal Oligocene, Yoder formation. Goshen County, Wyoming.

Specific characters. A large form. Trigonid of M_2 low and talonid fairly large and broad. Talonid of M_1 broad and rounded posteriorly. P_4 with pronounced posterior accessory tubercle half way up on the principal cusp. Principal cusp erect. Internal cingulum incomplete at the base of principal cusp. External cingulum faintly developed. (See Fig. 3.)

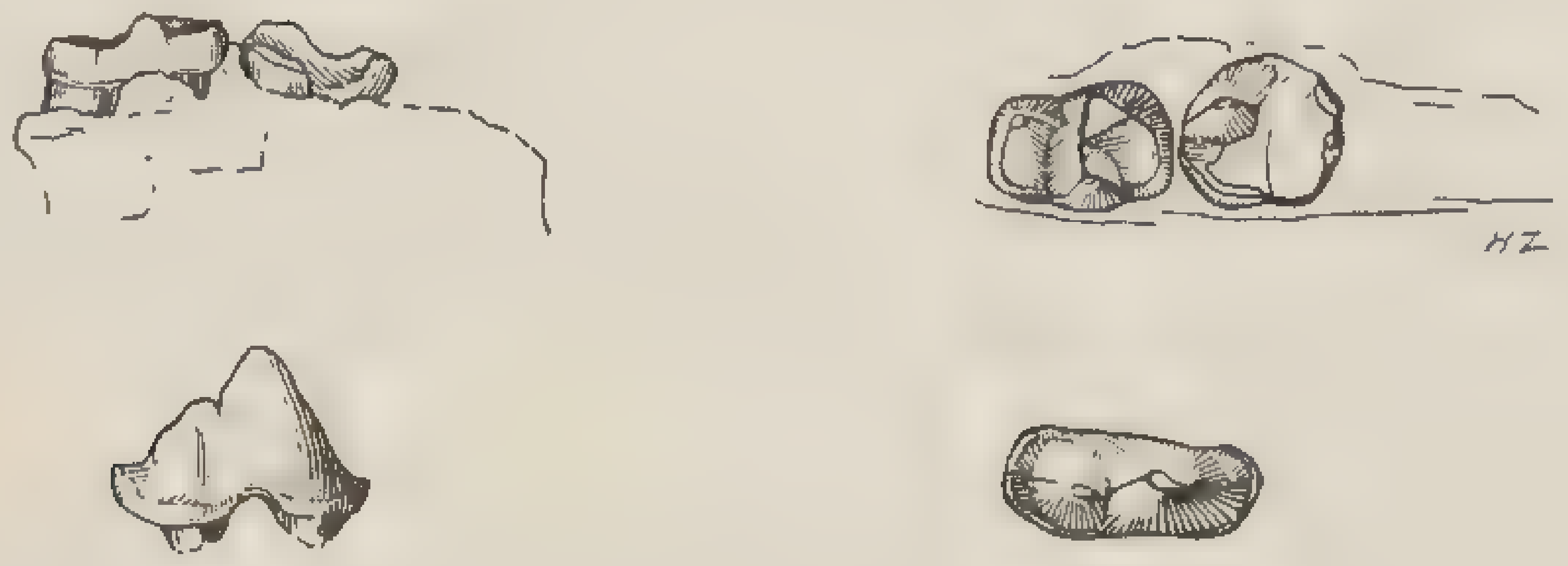

FIG. 3. *Miacis matthewi.* Above, lingual and superior views of M_2 and part of M_1. Below, external and superior views of P_4. Natural size.

Discussion. M. matthewi is one of the largest known members of this genus. In general it is about the size of *M. longipes* (Peterson) from the upper Uinta. It is different from that species, however, in the following characters: 1, Deeper ramus. 2, Principal cusp of P_4 more erect, posterior accessory cusp more pronounced and internal cingulum incomplete. 3, Talonid of M_1 broader. M_2 larger. In the proportionately larger size of M_2, *M. matthewi* is closer to *M. medius*

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[1] Named in honor of the late Dr. W. D. Matthew, author of the "Carnivora and Insectivora of the Bridger Basin, Middle Eocene," etc.

Matthew of the lower Washakie but of course is different from that species in size and in the reduced anterior basal cusp of P_4.

The relationship of *M. matthewi* to the other species of this genus will remain obscure until more satisfactory material is discovered. For the present, however, there seems to be no good reason for not considering this species an end member of a *M. medius-longipes* line of *Miacis* evolution. It is the last known survivor of that genus.

Measurements

	mm.
P_3–M_2 length (estimated)	36.5
Length of P_4	11.0
Width of M_1 across talonid	6.5
Length of M_2	7.5

Superfamily OXYAENOIDEA

Family HYAENODONTIDAE

Hemipsalodon cooki[1] sp. nov.

Type. Anterior portion of left mandible with P_3–M_1 and the alveoli of C and P_{1-2}. No. H. C. 530 Cook Museum, Agate, Nebraska. Found by H. J. Cook, 1932. Associated is the distal end of the left humerus, M. C. Z. No. 2,093. Found by E. M. Schlaikjer, 1931.

Horizon and locality. Basal Oligocene. Yoder formation. Goshen County, Wyoming.

Specific characters. Smaller in size than *H. grandis* Cope, but much larger than *Pterodon africanus* Andrews. Diastema between P_2 and P_3. Canine proportionately smaller than *H. grandis.* Width of M_1 about one-half its length. Humerus very massive and very broad distally. (See Figs. 4 & 5.)

Discussion. In 1885 Professor Cope described a right lower creodont jaw containing the crown of M_3 and the roots of all the other teeth from the lower Oligocene of the Cypress Hills, Canada. To this jaw he applied the name *Hemipsalodon grandis.* In a later publication (1891 pp. 6–7, pl. II) a fuller description was given and the specimen was figured. In 1908 Lambe (p. 61, pl. VII, Figs. 7–8) described and figured a single canine tooth from the same beds which he rightfully referred to Cope's genus and species. Until 1931 no other material of this largest known North American creodont (equalled in size perhaps by *Harpagolestes* of the Eocene) had been recorded. Matthew

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[1] Named in honor of Mr. Harold J. Cook of Agate, Nebraska.

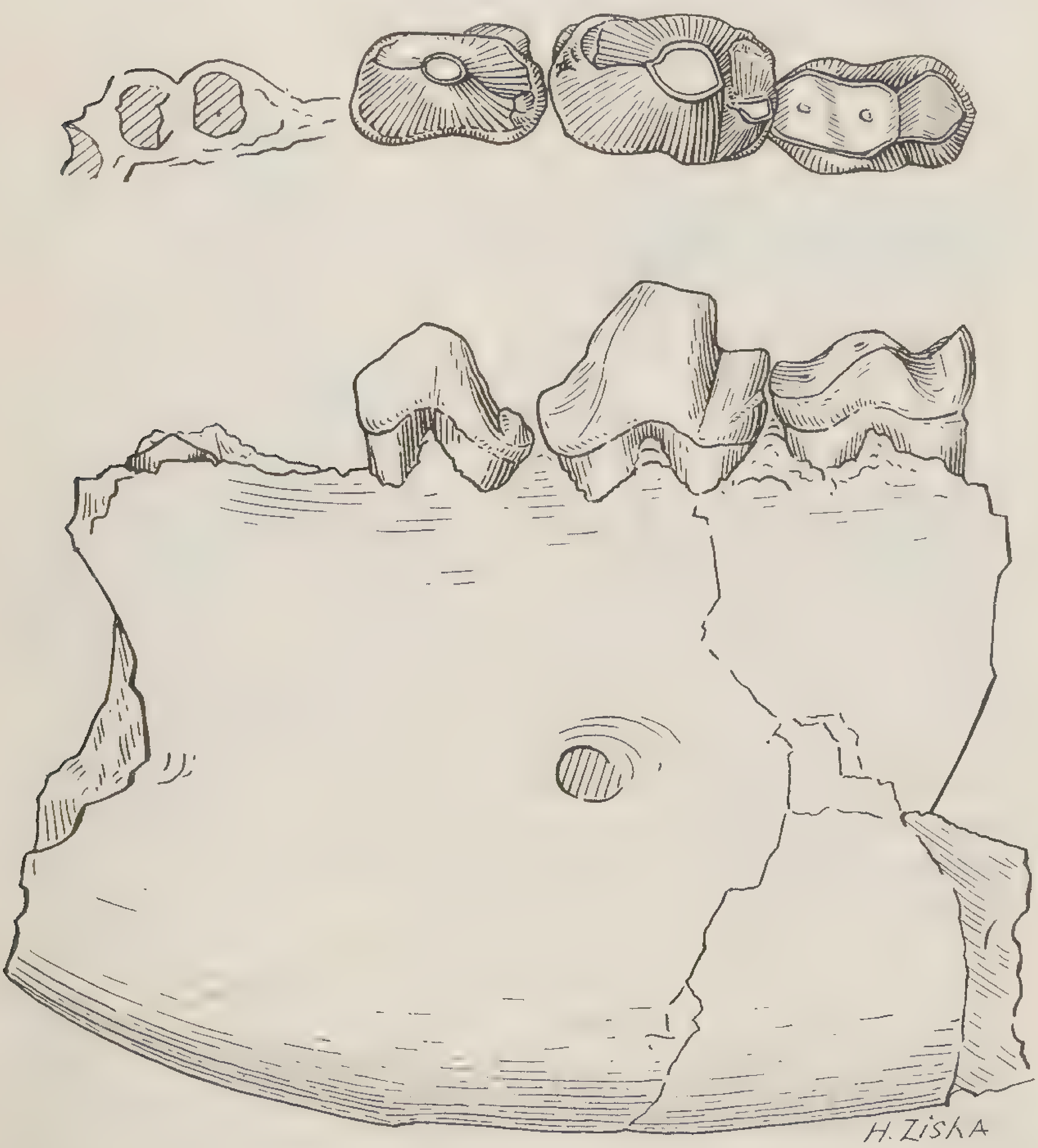


Fig. 4. *Hemipsalodon cooki.* Above, superior view of P_3–M_1. Below, external view of left ramus fragment. Natural size.

(1901, p. 20) and others have considered this genus as synonymous with *Pterodon* of Europe. A study of the newly discovered material and a reconsideration of all the available information, however, causes the author to regard Cope's genus as valid. That *Hemipsalodon grandis* and *H. cooki* belong to the same genus is established by the following similarities:

1. Large, deep and compressed mandible.
2. Position and proportions of the cheek teeth.
3. Development of the symphysial region.
4. Position of the mental foramina.

The differences between the two species have been cited above. It is unfortunate that none of the upper dentition is known. On the basis of the available data, however, the following characters of *Hemipsalodon* may be regarded as distinguishing it from *Pterodon:*

1. Much larger in size.
2. M_3 proportionately smaller.
3. M_1 proportionately less reduced and with large talonid.
4. P_4 proportionately heavier and with a much better developed postero-internal basin. That the two genera are closely allied is, nevertheless, beyond question and it is probable that *Hemipsalodon* was derived from some primitive form of *Pterodon* such as that represented by *P. leptognathus* Osborn from the Fayûm of Egypt. The appearance of *Hemipsalodon* and *Hyaenodon* in North America is significant in the history of faunal mixing which took place between the Old and New Worlds in earliest Oligocene times. These two specialized creodonts at that time arrived in the homeland from whence their ancestors had migrated early in the Eocene.

The distal end of the left humerus shows that that bone was of extraordinarily massive dimensions. It is considerably larger than the humerus of *Harpagolestes.* These facts indicate that the skeleton of *H. cooki* was large and very massive.

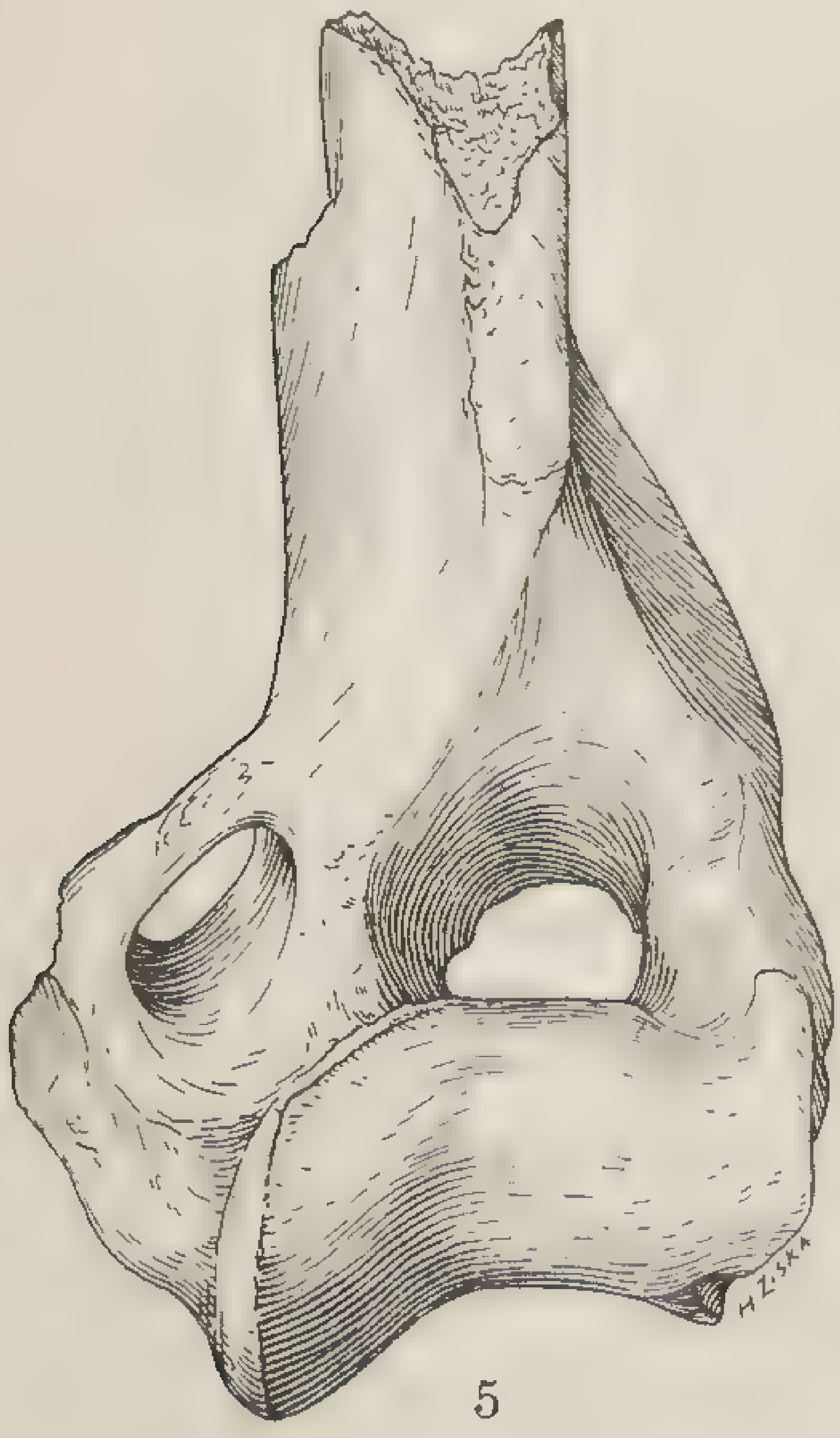
Measurements	mm.
P_{1-4} length	81.0
Length of P_2 (on alveoli)	20.5
Length of P_3	23.0
Length of P_4	27.0
Length of M_1	25.0
Width of M_1	11.0
Width of distal end of humerus	86.0

HYAENODON (NEOHYAENODON Thorpe) HORRIDUS Leidy

Material. Fragment of the upper left maxillary with P_4–M_2. H. C. No. 531 Cook Museum, Agate, Nebraska. Found by H. J. Cook, 1932.

Horizon and locality. Basal Oligocene. Yoder formation. Goshen County, Wyoming.

Discussion. In size this specimen is slightly smaller than *H. horridus*. The evolutionary stage of M^2 is about the same. The only important difference between the two is a better developed deuterocone on P^4 of the Yoder specimen. When more complete material is found this form may prove to be specifically distinct from the later species. Until then, it is tentatively referred to *H. horridus*.



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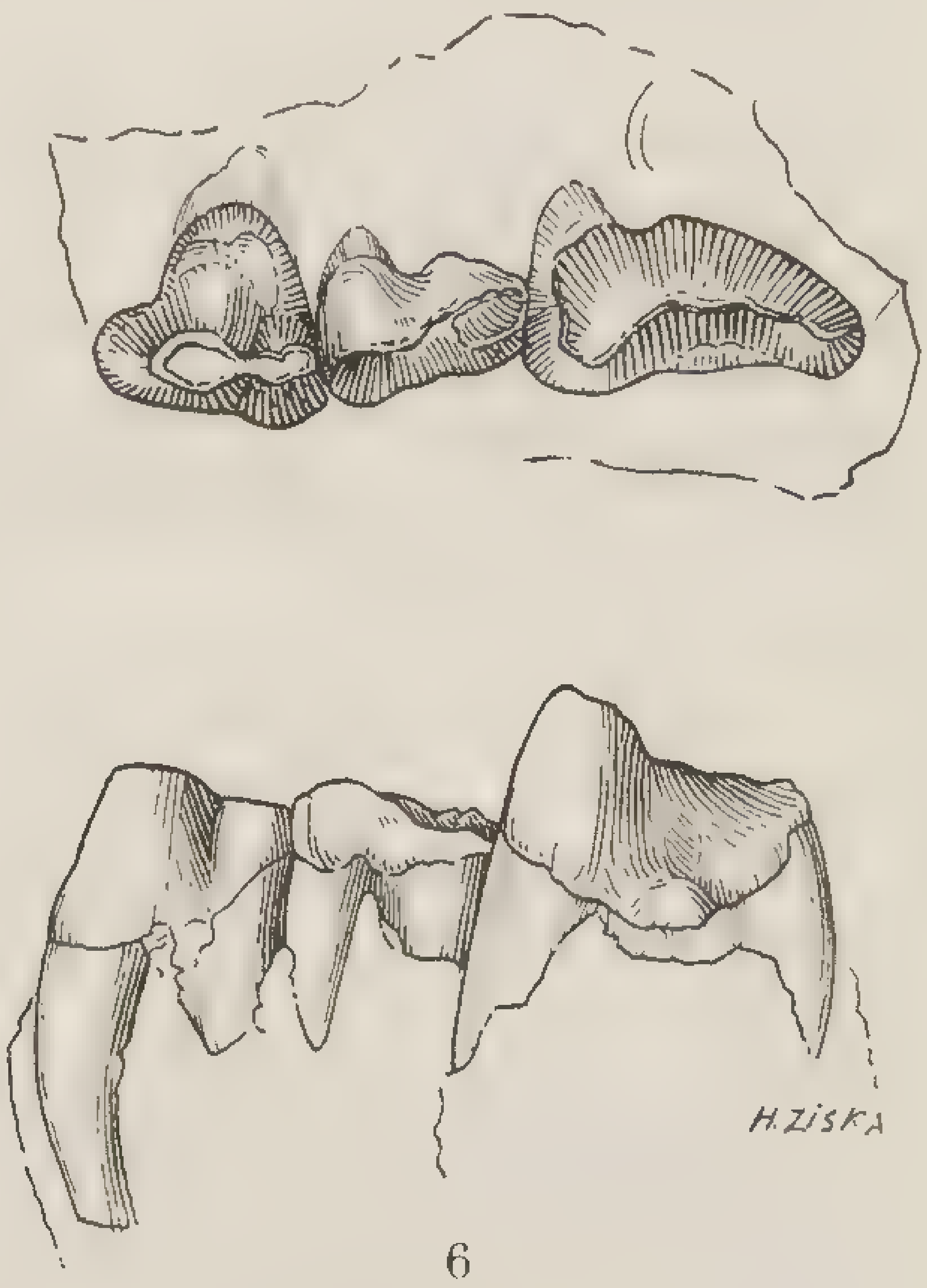

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FIG. 5. *Hemipsalodon cooki.* Anterior view of distal end of left humerus. One half natural size.

FIG. 6. *Hyaenodon horridus.* Above, crown view of P^4–M^2. Below, external view of the same. Two-thirds natural size.

Measurements

	mm.
P^4–M^2 length	62.0
Length of P^4	18.5
Width of P^4	17.0
Length of M^1	16.0
Length of M^2	26.5

Order PERISSODACTYLA

Superfamily EQUOIDEA

Family EQUIDAE

? MESOHIPPUS sp.

Horizon and locality. Basal Oligocene Yoder formation, Goshen County, Wyoming. Collected by E. M. Schlaikjer, 1931.

Description and discussion. The specimen is a jaw fragment containing a single tooth, left M_2, M. C. Z. No. 2,085 (Fig. 7). The tooth appears to represent a form intermediate between *Epihippus* and *Mesohippus*. It is somewhat nearer to the former in size and in that the paraconid retains a position internal to the fore and aft alignment of the metaconid-metastylid and entoconid cusps. Of the known species of this genus this specimen seems nearest to *E. intermedius* Peterson (1931, pp. 66–68). *E. intermedius* is, of course, much closer to *Mesohippus* than any of the other known *Epihippus* species and may, as suggested by Peterson, represent a distinct genus. The affinities of the Yoder specimen seem rather closer to *Mesohippus* than to *Epihippus* especially in the greater breadth of the tooth in proportion to its length and in a better developed endostylid. For these reasons it has been assigned very tentatively to that genus. Of the described species it is very close to *Mesohippus westoni* Cope from the lower Oligocene of the Cypress Hills.

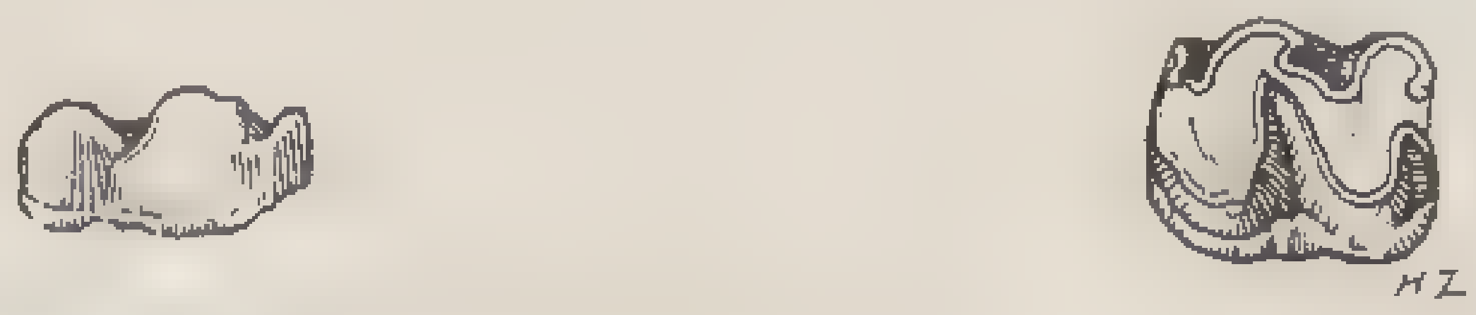

FIG. 7. ? *Mesohippus* sp. Lingual and superior views of left M_2. Natural size.

Measurements

	mm.
Antero-posterior length	9.5
Greatest width	8.0
Height of crown at metaconid	4.5

Superfamily BRONTOTHERIOIDEA

Family BRONTOTHERIIDAE

ATELEODON OSBORNI[1] gen. et sp. nov.

Type. Symphysial region of a lower jaw and associated left M_2. Adult M. C. Z. No. 2,100a and No. 2,100b. Collected by E. M Schlaikjer, 1931.

Paratype. Anterior part of right ramus containing M_1, Young. M. C. Z. No. 2,099. Collected by E. M. Schlaikjer, 1931.

Horizon and locality. Basal Oligocene, Yoder formation. Goshen County, Wyoming.

Generic and Specific Characters. Canine and incisors greatly reduced or absent. P_1 diminutive. P_2 much reduced. Symphysis short and shallow. Chin convex. Cingulum incomplete over external surfaces of proto- and hypoconids. Crowns of M_1 and M_2 proportionately tall. M_1 proportionately small. (See plates 2, 3, 4 and 5.)

Discussion. A character of this specimen not to be found in any other recorded species and one which seems incredible for any titanothere to possess is the apparent great reduction or complete loss of the lower canines and incisors. No teeth are present in the type jaw fragment, although the roots of two and the alveoli of two others are preserved. These are the roots and alveoli of the premolar series. The most anterior tooth was single rooted and the central vertical ridge on the posterior wall of the alveolus precludes the possibility of the root representing a much reduced and antero-posteriorly compressed canine. It is undoubtedly the root of P_1. Immediately behind this root are the roots of P_2 which show that that tooth was much reduced in size. The succeeding alveoli represent P_{3-4}. The whole premolar series was very much shortened,— a character also shown in the paratype jaw. For a distance of 66 mm. in front of P_1 the bone tapers to a thin edge. The most anterior portion of the jaw, perhaps not more than a half to three-quarters of an inch, is broken away. The preserved portion, however, is sufficient to indicate that the tapering continued anteriorly. The edge present does not show the slightest evidence of a normal deep canine alveolus which ought to be there if that tooth had been present. This character of the jaw cannot be the result of erosion for the original surface and texture of the bone is clearly shown, and there is no indication of any old age or pathological condition.

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[1] From the Greek α without, τελεος distant, οδων teeth. Named in honor of Professor Henry Fairfield Osborn, author of "The Titanotheres of Ancient Wyoming, Dakota and Nebraska," etc.

The paratype jaw presents the roots of P_3 and D.P.$_4$ and the first molar. Although the symphysis is missing, characters such as the proportionately small premolars and shallow ramus as well as the form and dimensions of M_1 show that it is probably *Ateleodon osborni*. Both were collected from exactly the same geological level and only a few feet apart.

In size, *Ateleodon osborni* is intermediate between *Teleodus uintensis* Peterson of the Duchesne and *T. primitivus* Lambe of the lower Chadron. It differs so far as is known from these, however, aside from the great reduction or complete loss of the lower canines and incisors, in the following characters:

1. A more shallow ramus.
2. Chin more gently convex and much more shallow.
3. Much greater reduction of P_2.

M_1 is of the same width as in *T. uintensis* although it is longer and taller crowned. M_2 is about the same size.

The great reduction or complete loss of the lower canines and incisors is a character certainly of more than specific value in the titanothere group. *Ateleodon osborni* represents an aberrant form which probably became extinct at the end of Yoder times or early in the Chadron. It is indicative of one more significant stage in the great adaptive radiation of the titanotheres.

Measurements

	mm.
Length of P_2 on alveoli	14.5
Greatest length of M_1	43.5
Greatest width of M_1	24.5
Greatest length of M_2	49.5
Greatest width of M_2	30.5

BRONTOPS ? BRACHYCEPHALUS (Osborn)

Material. Anterior fragment of left lower jaw with P_4 and M_1, and associated right M_2 and left I^2, M. C. Z. No. 2,098 a, b, & c. (See plates 5 and 6.). Collected by E. M. Schlaikjer, 1931.

Horizon and locality. Basal Oligocene. Yoder formation. Goshen County, Wyoming.

Discussion. In size, the specimens compare most favorably with *B. brachycephalus* although somewhat smaller. The known portion of the jaw shows that the ramus was rather shallow, especially anteriorly. P_4 represents about the same evolutionary stage as in *B. brachycephalus.* It has, however, a very much developed external cingulum, a character also present in M_{1-2}. M_2 also differs from this species in that the external surfaces of the protoconid and hypoconid display greater obliquity; the postero-external corner is much more developed; and, the anterior portion of the tooth is much narrower than the posterior. The upper dentition is represented only by the left I^2 which exhibits a perfectly smooth rounded crown.

When more material is known, these specimens may be found to represent a new species,— a stage perhaps directly ancestral to *Brontops.*

Measurements

	mm.
Greatest length of P_4	40.0
Greatest width of P_4	32.0
Greatest length of M_2	70.0
Greatest width of M_2	44.0
Length of I^2 crown	8.0
Width of I^2 crown	7.5

Superfamily RHINOCEROTOIDEA

Family HYRACODONTIDAE

HYRACODON ISCHYROLOPHUS[1] sp. nov.

Type. Left M^3 No. H. C. 532 Cook Museum, Agate, Nebraska. Found by H. J. Cook, November, 1932.

Horizon and locality. Basal Oligocene. Yoder formation. Goshen County, Wyoming.

Specific characters. Extension of ectoloph, posterior to metaloph well developed. Postfossette pronounced. Parastyle internal to paracone. Constriction between protocone and protoloph. Posterior of the tooth broad and straight-margined.

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[1] From the greek *ισχυρος* strong, *λοφος* ridge, in allusion to the well developed post-metaloph portion of the ectoloph.

Discussion. The specimen here described is the earliest known *Hyracodon* and even though the material consists only of a single tooth it is worthy of considerable attention. To be sure, there is some individual variation in M^3 in each of the several described species but these variations are never interspecific. There are, therefore, certain M^3 characters in *H. ischyrolophus* (listed above) which are specifically distinctive, and which indicate a morphologic stage intermediate between *Prothyracodon obliquidens* (Scott and Osborn) of the Uinta and *H. petersoni* Wood of the Chadron, but somewhat nearer the latter (see Fig. 8). Dr. H. E. Wood in his paper on *Hyracodon petersoni* (1926, p. 317) states that it is possible to derive all known species of *Hyracodon* from *H. petersoni* "or perhaps, from something very close to it, with a larger posterior buttress on M^3." *H. ischyrolophus*, so far as is known, seems to fulfill Dr. Woods' prophecy. There is, however, still a considerable gap between *Prothyracodon obliquidens* and *H. ischyrolophus*.

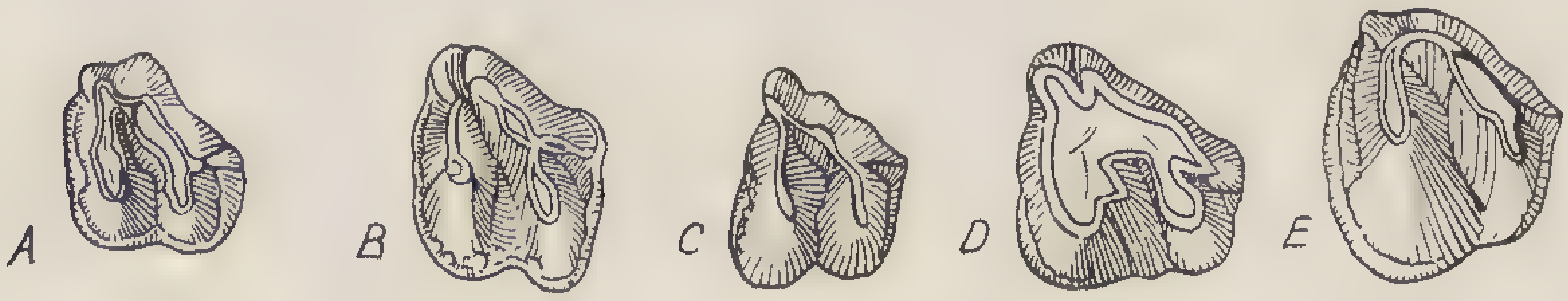

Fig. 8. Comparative drawings of the left M^3 of several hyracodont species. Arranged stratigraphically with the oldest at the left. A, *Prothyracodon obliquidens*. B, *H. ischyrolophus* type. C, *H. petersoni*. D, *H. nebrascensis*. E, *H. apertus*. A (reversed) and C after Wood, D after Leidy and E after Sinclair. Drawn to scale, x ⅔.

Measurements

	mm.
Antero-posterior diameter of M^3	18.0
Greatest width of M^3	22.0

Family RHINOCEROTIDAE

Caenopus yoderensis sp. nov.

Type. Left mandible fragment with M_{1-3} M. C. Z. No. 2,097. Collected by E. M. Schlaikjer, 1931.

Horizon and locality. Basal Oligocene, Yoder formation. Goshen County, Wyoming.

Specific characters. Intermediate in size between *Eotrigonias rhinocerinus* Wood from the upper Uinta and *Caenopus dakotensis* from the upper Oligocene. M_3 with minute internally placed posterior cingulum. M_1 proportionately small (See plate 7).

Discussion. Caenopus yoderensis forms an admirable morphological and stratigraphical stage intermediate between *Eotrigonias rhinocerinus* and *C. dakotensis.* It is different from the latter, in so far as is known, in its smaller size, in the proportionately small M_1 and in the presence of a diminutive posterior cingulum on M_3. In all of these characters, however, it is definitely in advance over *E. rhinocerinus. C. mitis* is a much larger form than any of the other species but it too could easily have been derived from *C. yoderensis.* It probably represents a line of more rapid development in the adaptive radiation of this genus than does *C. dakotensis.* The phylogenetic position of ? *C. premitis* is an open question (See Gregory and Cook, 1928, p. 19 and Wood, 1931, p. 426). Its affinities are tentatively suggested in Fig. 9.

Comparative measurements (in mm.)

	E. rhinocerinus	*C. yoderensis*	*C. dakotensis*	*C. mitis*
M_1 length	15.4	16.0	21.5	26.0
width	10.0	13.0	15.5	17.5
M_2 length	17.2	24.0	27.0	?28.0
width	10.3	14.6	16.5	?19.0
M_3 length	17.7	24.1	26.3	31.0
width	10.5	15.4	16.5	?19.0

SUBHYRACODON WOODI[1] sp. nov.

Type. Right mandible fragment with DP_4 and M_{1-3}. M. C. Z. No. 2,096. Collected by E. M. Schlaikjer, 1931.

Horizon and locality. Basal Oligocene. Yoder formation. Goshen County, Wyoming.

Specific characters. Smallest known *Subhyracodon.* P_4 molariform, although the endoconid cingulum is stronger and extends farther forward, it does not completely block off the inner end of the talonid valley, however. The antero-internal cingulum is slightly stronger on P_4 than on the molars but its union with the anterior base of the metaconid is as feebly developed. Anterior and posterior cingula

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[1] Named in honor of Dr. Horace Elmer Wood, 2nd.

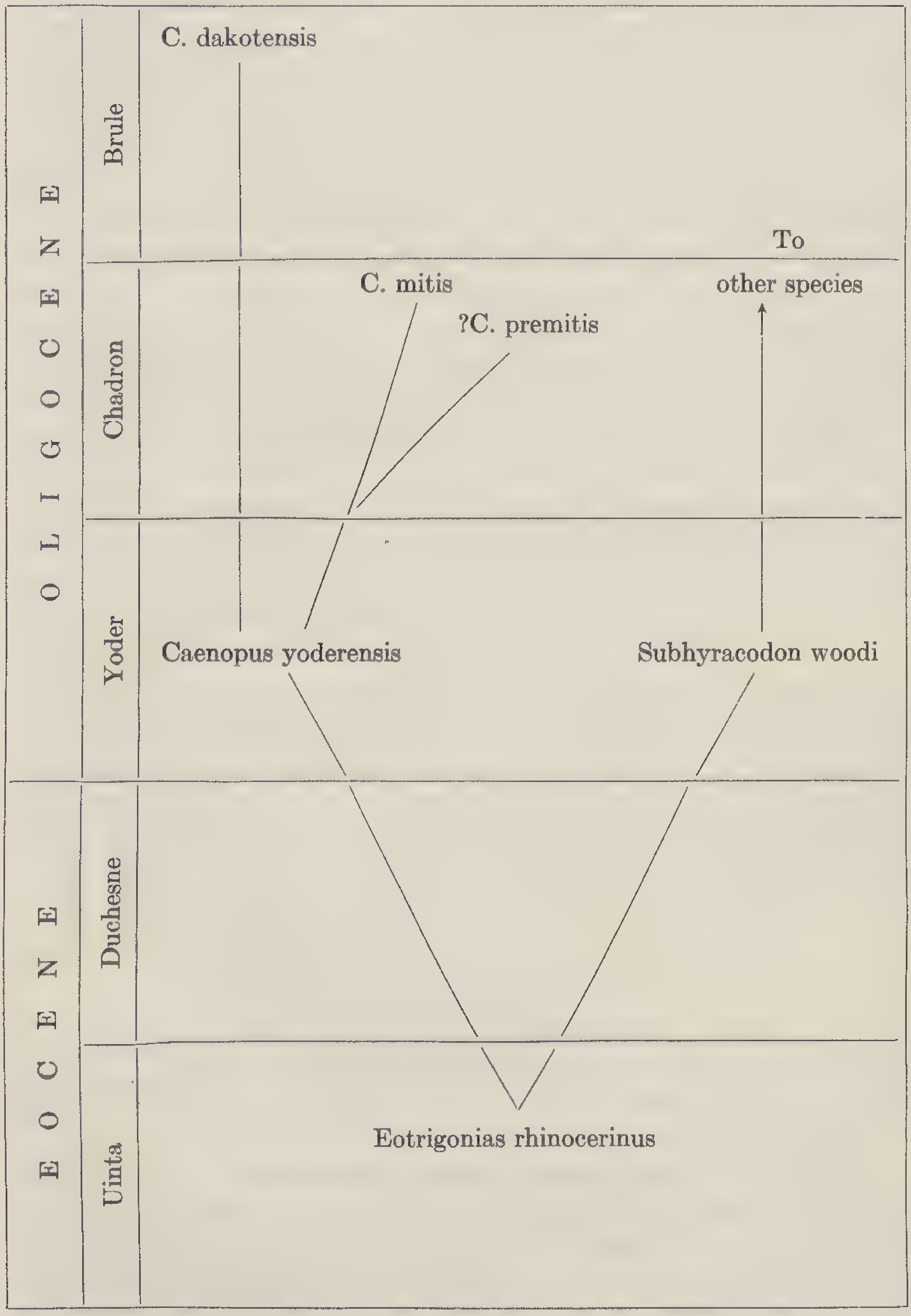
OLIGOCENE
EOCENE
Brule
Chadron
Yoder
Duchesne
Uinta
C. dakotensis
To
other species
C. mitis
?C. premitis
Caenopus yoderensis
Subhyracodon woodi
Eotrigonias rhinocerinus

FIG. 9. Diagram showing the affinities of some of the early Oligocene rhinoceroses. Schlaikjer 1933.

strong. External cingulum weak on P_4 and absent (?) on the molars. M_1 and M_2 subequal in size. Premolar series short with P_1 about one-half (measurements on alveoli) the length of P_2. Symphysis shallow (See plate 8).

Discussion. The inferior tooth formula, as known, is I1+, C0, P4, M3. The symphysis contains the inferior portion of a fairly large alveolus which is probably that of I_2 and its position in the jaw indicates that that tooth was somewhat procumbent. Of the known species of *Subhyracodon*, *S. woodi* is nearest to *S. copei* and it possesses no characters which would eliminate it as ancestor to all the known species. Its stratigraphic occurrence, of course, is also correct for such a position. This suggested phylogeny is expressed in Fig. 9.

Measurements

	mm.
Length of P_1 on alveoli	9.0
Length of P_2 on alveoli	16.0
Length of P_3 on alveoli (estimated)	19.5
Length of P_4	24.0
Length of M_1	28.0
Width of M_1	19.5
Length of M_2	30.0
Width of M_2	20.0
Length of M_3	31.0

Order ARTIODACTYLA

Suborder PECORA

Family HYPERTRAGULIDAE

LEPTOMERYX YODERI sp. nov.

Type. Left M^3 and associated left lower ramus with P_2–M_3 M. C. Z. No. 2,095. Collected by E. M. Schlaikjer, 1931.

Horizon and locality. Basal Oligocene. Yoder formation. Goshen County, Wyoming.

Specific Characters. Paracone- metacone crest straight. Mesostyle rather feeble. External rib on metacone completely lacking. Median internal cingule on upper molar small and shared by the bases of both the protocone and metaconule. A weak anterior cingulum. M_3 with interior and external cusps of the heel almost completely confluent. M_2 considerably larger than M_1. (See Fig. 10).

Discussion. Seven species of *Leptomeryx* have been previously described: four from the lower Oligocene, two from the upper Oligocene or lower Miocene and one, *L. evansi,* has been distinguished from the array of specimens collected from the middle Oligocene or Oreodon beds. Three of these species, *L. esulcatus — mammifer — semicinctus* were established by Cope on one, two and three isolated teeth respectively. *L. speciosus* Lambe was also described from isolated teeth and Matthew (1926, p. 4) casts doubt on the validity of *L. transmontanus* Douglass, the type material of which consists of upper cheek teeth and part of the skull. It seems, therefore, that whether or not these species are valid, can be determined only by the discovery of more complete specimens, especially in the type localities and by a more thorough study of the known *Leptomeryx* material.

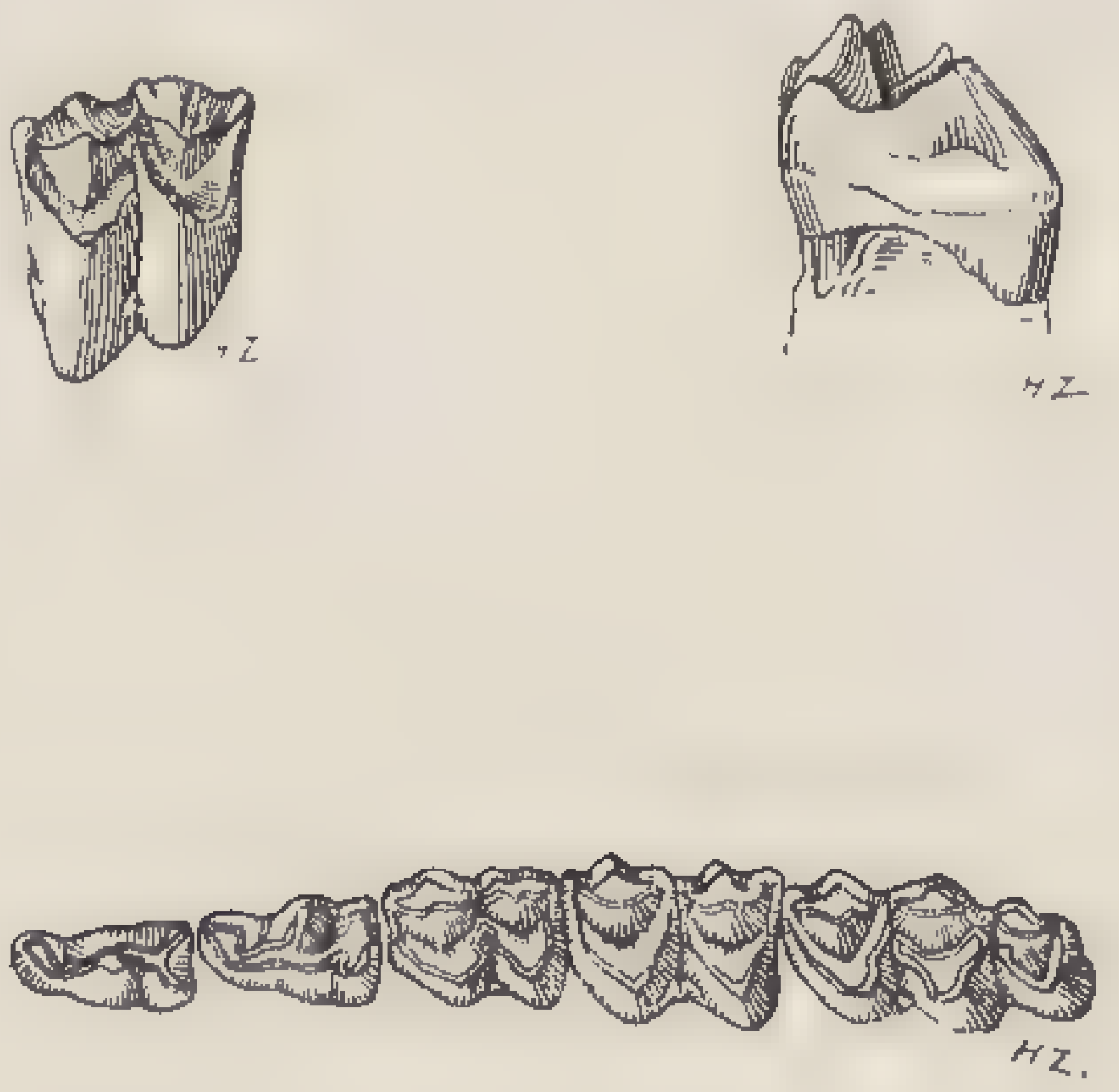

FIG. 10. *Leptomeryx yoderi* sp. nov. Crown and anterior views of left M^3 and left P_3 to M_3. Natural size.

The species described above is the earliest *Leptomeryx* recorded and in several respects, such as the proportionately small size of M_1 and the less complicated lower premolars, it is less specialized than the other species. P_{3-4} are less complicated especially in that the postero-internal branch from the main cusp of P_4 is a simple straight crest, and that the branching of the posterior crest of P_3 is short and open. In size this specimen is considerably larger than *L. evansi* Leidy, *L. esulcatus* Cope and *L. transmontanus* Douglass. It is slightly larger than *L. speciosus* Lambe and slightly smaller than *L. mammifer* Cope.

It is somewhat smaller than *L. obliquidens* Lull and much smaller than *L. semicinctus* Cope which is the largest of all the described species.

Several skeletal parts are preserved. They are, the distal end of the left radius, the proximal end of the fused metatarsals III and IV and the right calcaneum and astragulus. None of these skeletal elements possess characters which may be regarded as distinctive of this species, unless their proportionately small size may be considered as such.

Measurements

	mm.
Greatest length of M^3	8.6
Greatest width of M^3	10.4
Distance from M_1–M_3 on alveoli (center)	25.2
Greatest length of M_1	6.3
Greatest width of M_1	5.0
Greatest length of M_2	7.6
Greatest width of M_2	5.5
Greatest length of M_3	11.3
Greatest width of M_3	5.0
Greatest length of P_4	7.0
Greatest width of P_4	3.5
Greatest length of P_3	6.4

CONCLUSIONS

1. To a series of fluviatile deposits in Goshen Hole resting with unconformity on the Cretaceous and overlain with conformity or disconformity by the lower Oligocene Chadron formation is applied the new formational name *Yoder.*

2. The Yoder formation represents the earliest Oligocene deposition known in the Great Plains region and because of stratigraphic and faunal evidence its age is regarded as post-Duchesne and pre-Chadron.

3. The species which are described as new from the Yoder are as follows: *Miacis matthewi, Hemipsalodon cooki, Ateleodon osborni* (a new genus), *Hyracodon ischyrolophus, Caenopus yoderensis, Subhyracodon woodi* and *Leptomeryx yoderi.*

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EXPLANATION OF PLATES

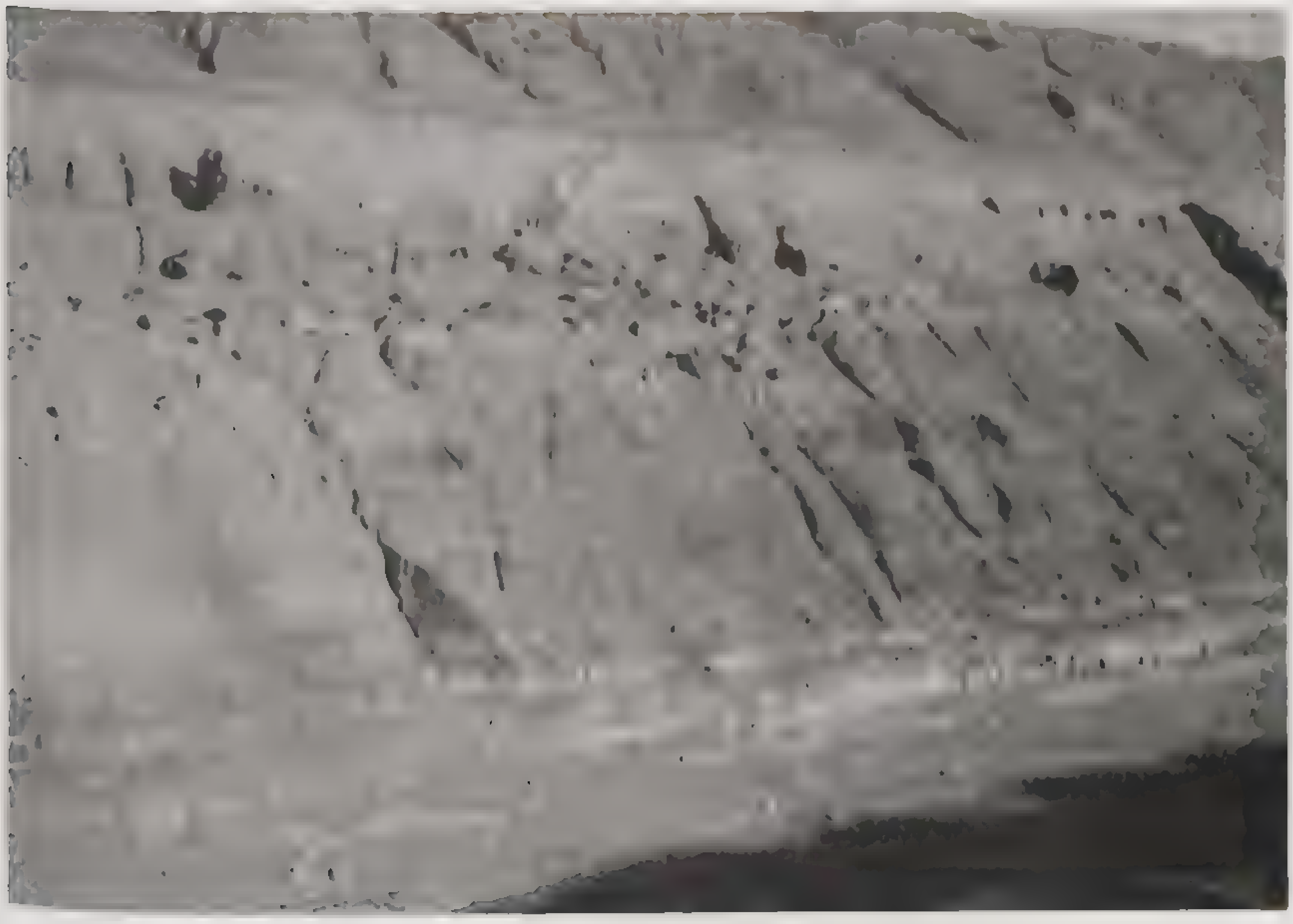
PLATE 1

PLATE 1

Fig. 1. Type locality of the Yoder formation. East bank of the Fort Laramie Canal.

Fig. 2. Block of coarse sandstone containing type jaw of *Subhyracodon woodi.*

Photographs by Erich M. Schlaikjer



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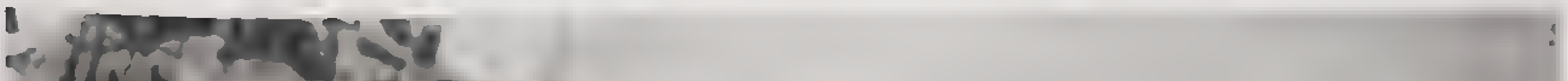

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PLATE 2

PLATE 2

Ateleodon osborni Schlaikjer

Type. Anterior part of right mandible. Natural size.

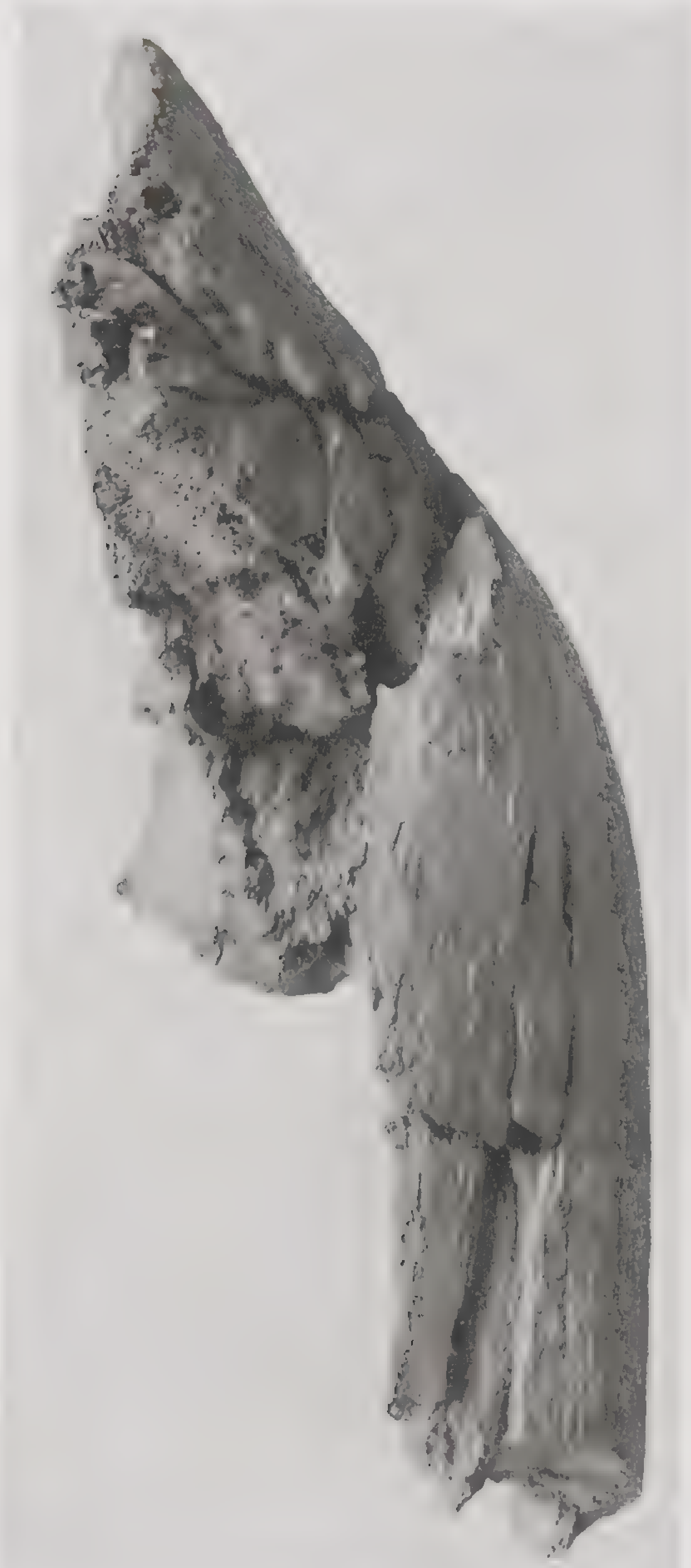


PLATE 3

PLATE 3

ATELEODON OSBORNI Schlaikjer

Type. Superior view of the symphysial region, and left M_2. Natural size.

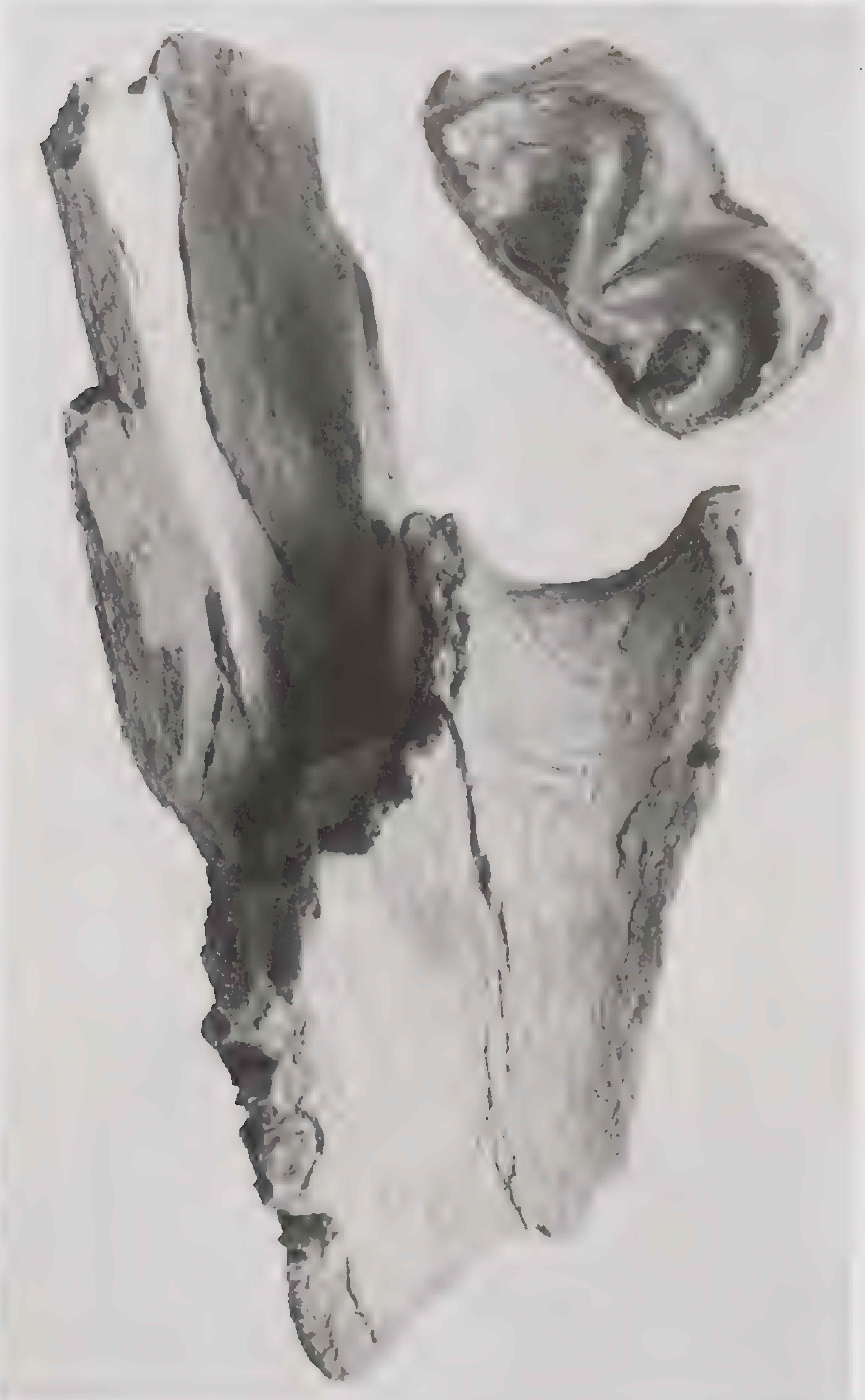


PLATE 4

PLATE 4

Ateleodon osborni Schlaikjer

Paratype, Anterior part of right mandible containing M_1. Young. Natural size.

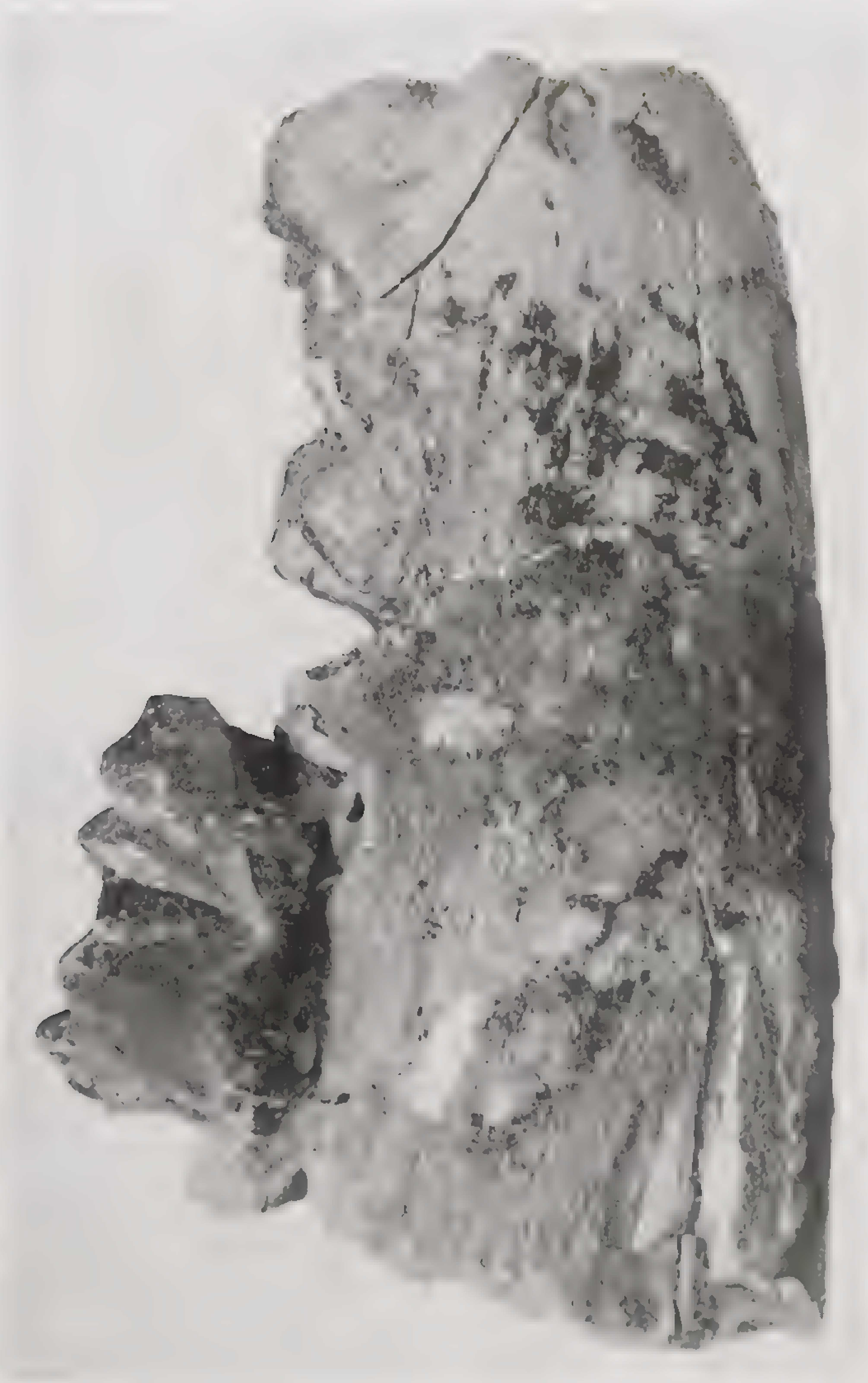
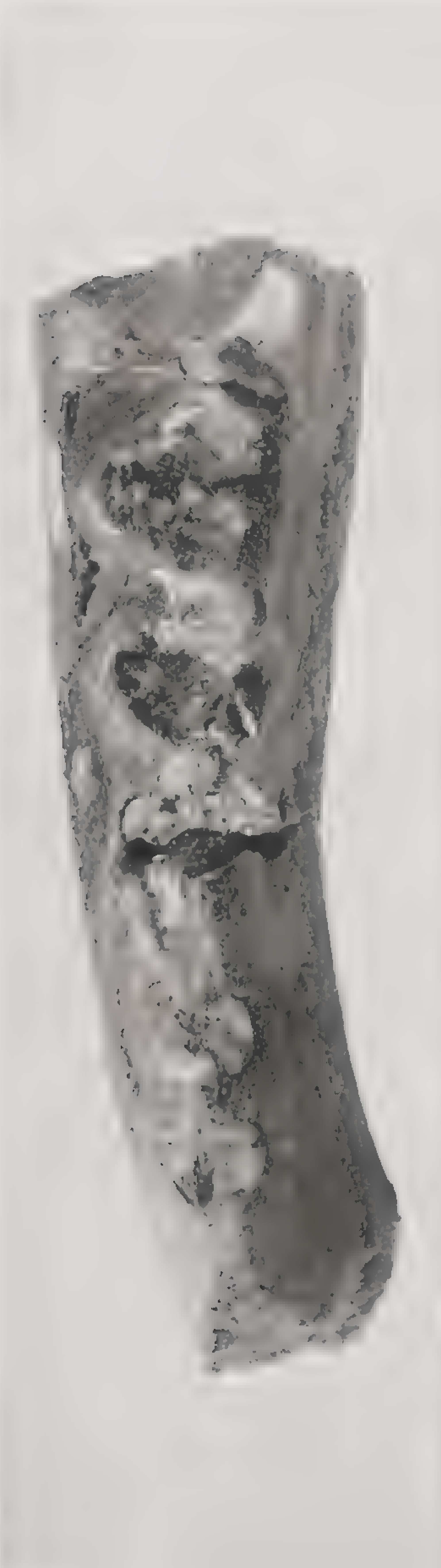


PLATE 5

PLATE 5

Fig. 1. *Ateleodon osborni.* Paratype. Superior view of anterior part of right mandible containing M_1. Natural size.

Fig. 2. *Brontops ? brachycephalus* (Osborn). Superior view of anterior part of left mandible containing P_4 and M_1, and right M_2. Two-thirds natural size.



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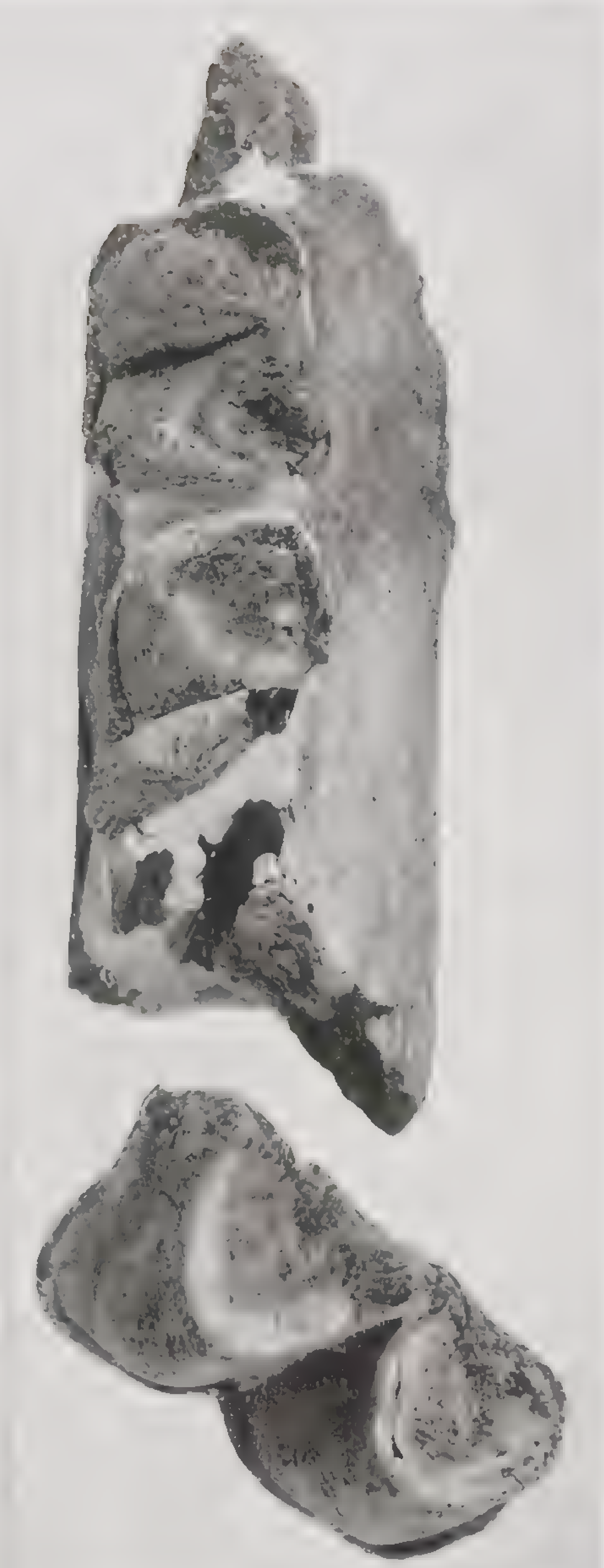

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PLATE 6

PLATE 6

Brontops ? brachycephalus Osborn

External view of anterior part of left mandible containing P_4 and M_1. Natural size.

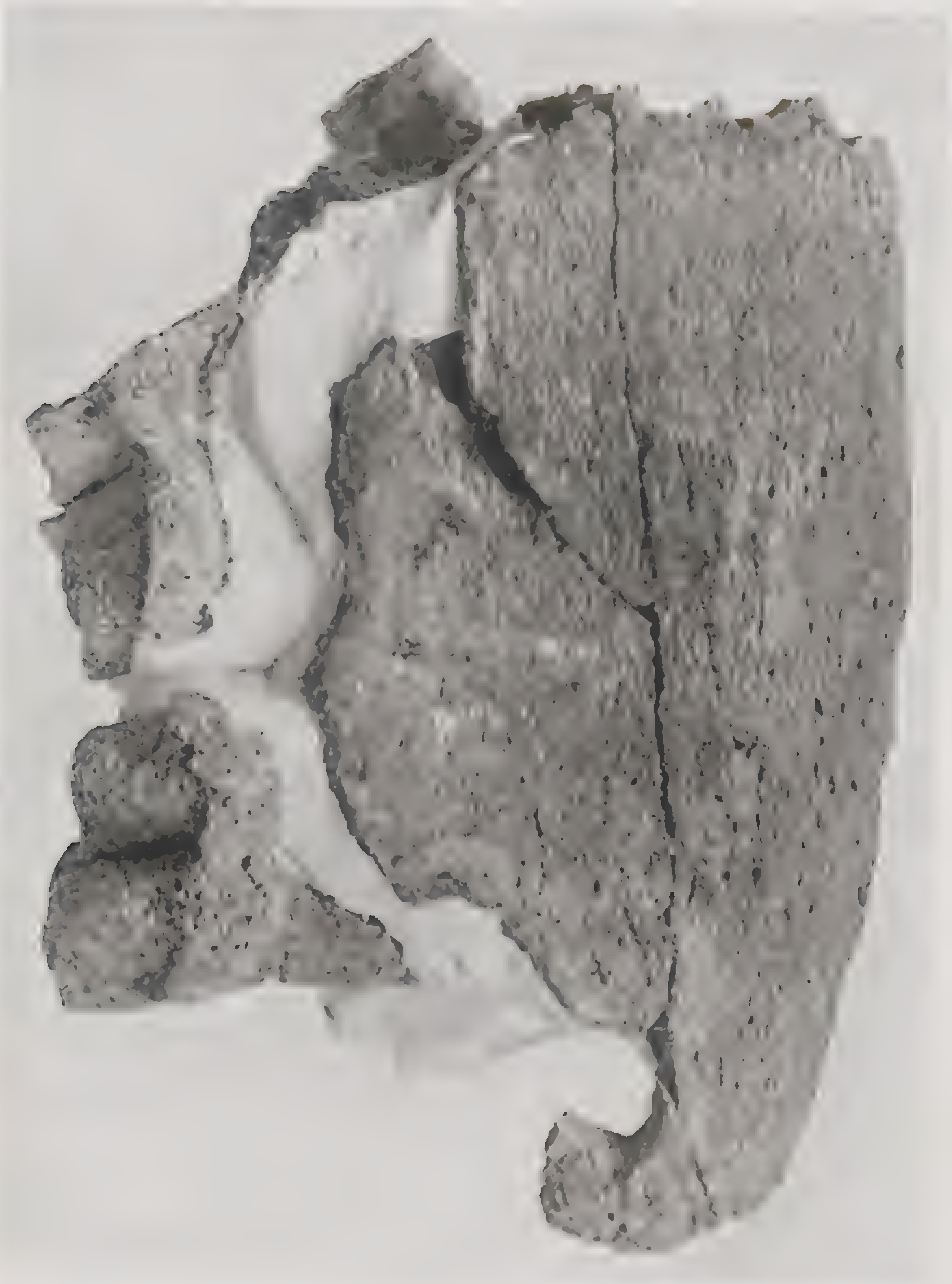


PLATE 7

PLATE 7

Caenopus yoderensis Schlaikjer

Type. Superior and internal views of left mandible containing M_{1-3}. Natural size.

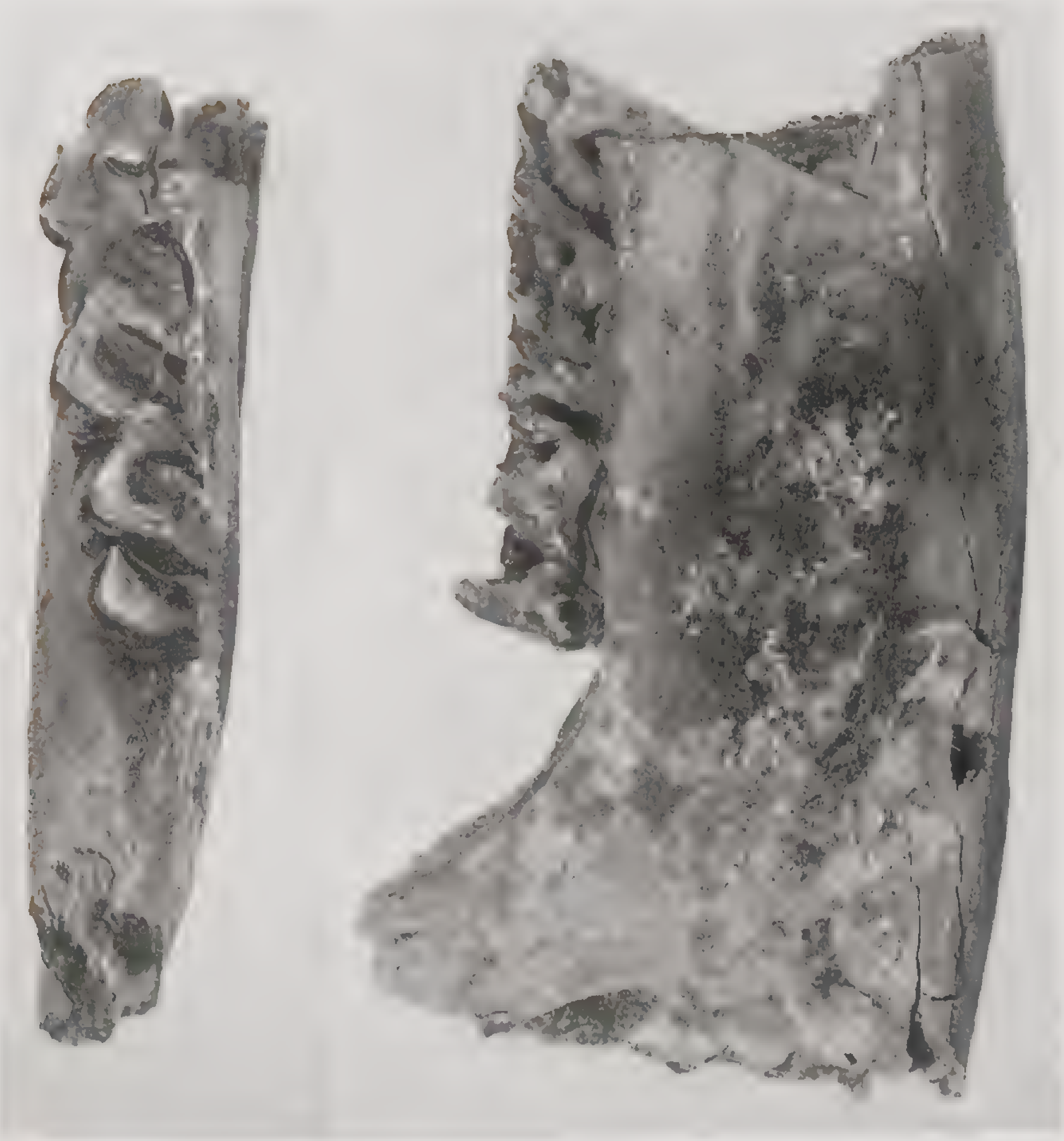


PLATE 8

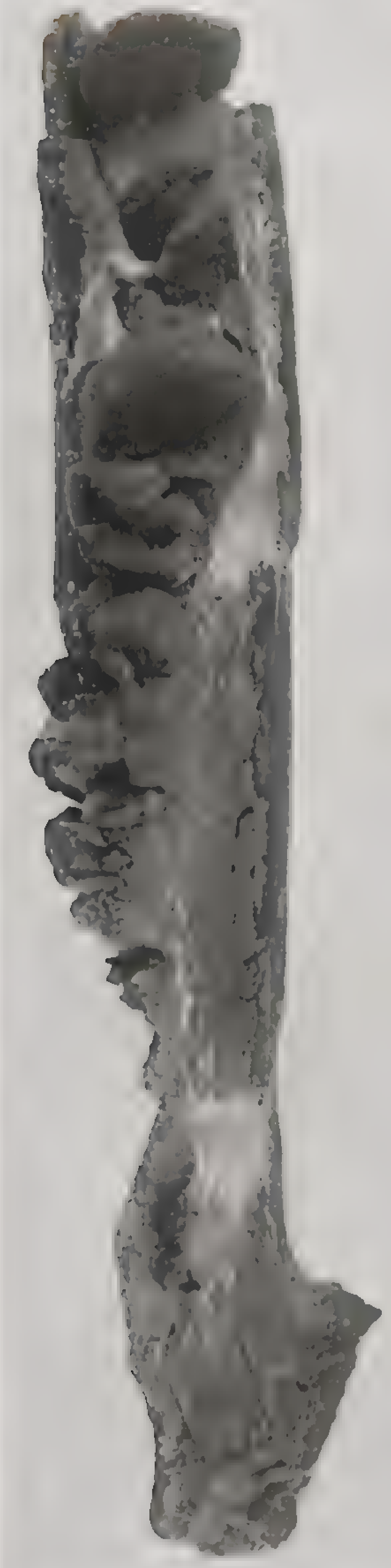
PLATE 8

SUBHYRACODON WOODI Schlaikjer

Fig. 1. Superior view of right mandible containing P_4 and M_{1-3}.
Fig. 2. Internal view of the same, showing P_4 not yet erupted.

Both figures two-thirds natural size

Plates 2–8, photographs by George Nelson



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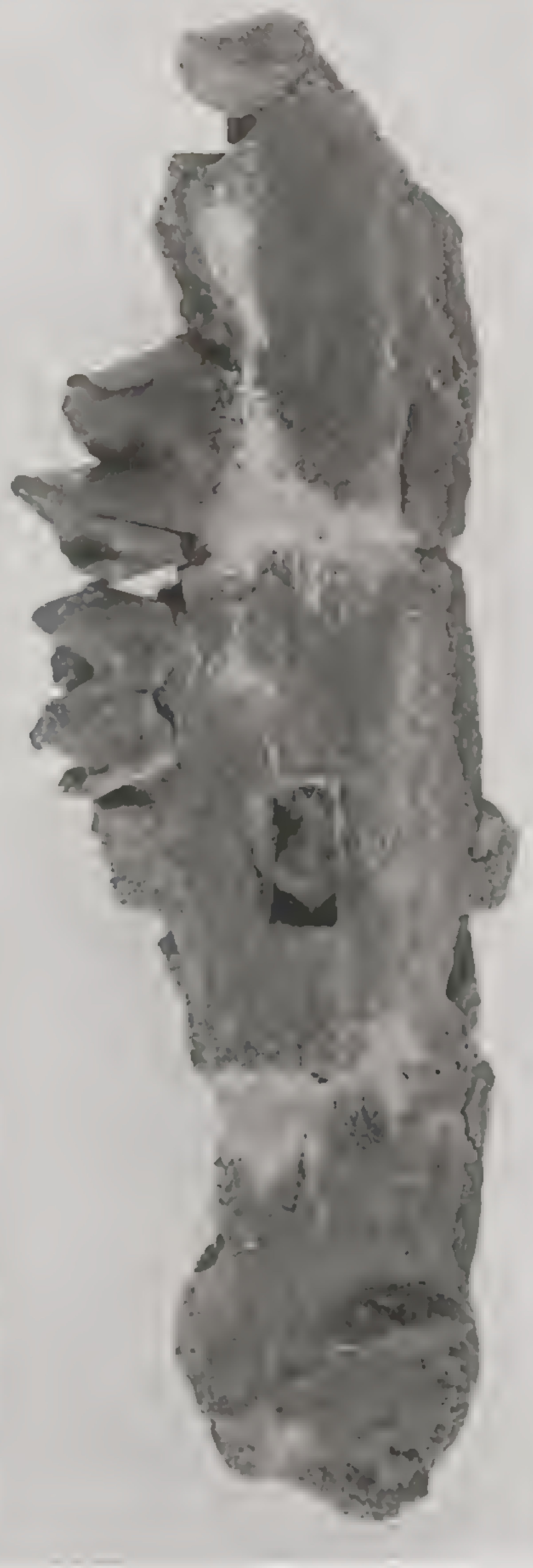

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Vol. LXXVI, No. 4

CONTRIBUTIONS TO THE STRATIGRAPHY AND PALAEONTOLOGY OF THE GOSHEN HOLE AREA, WYOMING

IV

NEW VERTEBRATES AND THE STRATIGRAPHY OF THE OLIGOCENE AND EARLY MIOCENE

By Erich M. Schlaikjer

With Forty-one Plates

CAMBRIDGE, MASS., U. S. A.
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May, 1935

P

PUBLICATIONS

OF THE

MUSEUM OF COMPARATIVE ZOÖLOGY

AT HARVARD COLLEGE

There have been published of the Bulletin Vols. I to LXV, LXVII–LXXV, LXXVII, of the Memoirs Vols. 1 to LII, LIV.

The Bulletin and Memoirs are devoted to the publication of original work by the Officers of the Museum, of investigations carried on by students and others in the different Laboratories of Natural History, and of work by specialists based upon the Museum Collections and Exploration.

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No. 4.—*Contributions to the Stratigraphy and Palaeontology of the Goshen Hole Area, Wyoming*

IV

New Vertebrates and the Stratigraphy of the Oligocene and early Miocene

By Erich M. Schlaikjer

INTRODUCTION

During the field seasons from 1930 to 1933 the writer carried out a geological and palaeontological investigation of the Goshen Hole Area in southeastern Wyoming for the Museum of Comparative Zoölogy at Harvard College. The partial results of this research have appeared in a series of articles dealing with: (1) the description of a new species of *Apternodus* and a study of the zalambdodont insectivores; (2) the Cretaceous formations, giving especial reference to a new member of the Lance, the description of a new *Triceratops* and the discussion of the phylogeny of the genus; and, (3) a new basal Oligocene formation,— the Yoder and its fauna, most of which was new. The present paper is the fourth and final part of these contributions and comprises a consideration of the Chadron, Brule and lower Miocene formations with a discussion of the faunae and descriptions of many new forms.

The writer wishes to acknowledge his sincere appreciation to Professor William K. Gregory for assistance and advice throughout this research. Acknowledgment is here made of the aid received from Dr. Thomas Barbour and the many courtesies extended by the Museum of Comparative Zoölogy. The Columbia University geology faculty, particularly Professors Charles P. Berkey and Douglass W. Johnson and Doctors H. N. Coryell and G. M. Kay have offered many valuable suggestions and criticisms. The encouragement of Professor Charles C. Mook of Brooklyn College and his many suggestions in the field during the summer of 1931 have been most welcome. To Professor Henry Fairfield Osborn and to the other members of the department of vertebrate palaeontology at the American Museum of Natural History the writer is indebted for the privilege of studying the specimens in that institution. The friendly attitude shown the writer and his associates by the citizens of Goshen County, Wyoming, has made the field work especially pleasant.

DESCRIPTIVE GEOLOGY

General Features

Exposures of the Pierre, Lance and Yoder formations of the Goshen Hole Area have been fully described previously. The remaining outcrops in the interior lowlands are mostly of the Chadron formation which is composed of green, yellow and reddish clays and sandstones. Except for an occasional promontory such as Red Bill Point and a few other more or less sinuous mesa-like expressions, which result from the impeded erosion of the resistant upper Chadron channel sandstones that cap the softer clays, the relief of Goshen Hole is low and gently rolling. Surrounding this vast topographic basin is the almost continuous escarpment which is from four hundred to a thousand feet in height. Exposed along the face of this escarpment are the soft pinkish Brule clays that form the less steep slopes near the base on which is developed a miniature bad-land topography, and the resistant gray sands and sandstones of the lower Harrison formation on which the steep upper limits are developed. The Harrison sediments are rather pervious and the Brule clays are relatively impervious, hence the contact of these two formations determines the most important water table of the uplands. This contact is disconformable in some places and unconformable in others. It is, therefore, quite irregular and frequently is inclined towards the face of the escarpment which results in the occurrence of many springs. This seepage results in the rapid disintegration of the clays that are soon washed or blown away. In this way the overlying more resistant sands and sandstones are undermined and the retreat of the escarpment is greatly enhanced.

The three hundred and seventy-five square miles of high upland table land is composed of the Harrison formation. Much of this formation is covered with alluvium but where exposures occur erosion has carved it into a bizarre relief mainly because of the variability of resistant and soft layers. A characteristic feature of these beds is the presence of a millenium of well-like excavations of all sizes from two to ten feet in diameter and three to fifteen feet deep. Apparently these are caused by wind action.

The drainage system of the area consists of the North Platte River with its main tributary the Laramie River and two tributaries of lesser importance,— Cherry Creek and Bear Creek. Along the North Platte River extensive terraces occur which are frequently from fifty to one hundred feet above the present level of the river. On these terraces are rather thick accumulations of sands and gravel which, as is shown by the presence of *Archidiskodon imperator*[1] and *Equus*, are Pleistocene in age. The Laramie River flows across the northwestern corner of the area. Where it crosses the Whalen Fault it has carved a canyon, the south wall of which is four hundred feet high. Deer and Six Mile Creeks are its tributaries which drain the "Military Flats" country just to the south of Old Fort Laramie. Their southwest-northeast trend has been determined, as has also the head of Cherry Creek, by structural conditions in the vicinity of the Whalen Fault. Horse Creek flows in from the southwest, turns abruptly and flows northward between Sixty Six and Bear Creek Mountains. G. I. Adams (1902, p. 25) has suggested that the head waters of Horse Creek used to flow eastward into Pumpkin Creek of Banner County, Nebraska before they were captured and diverted to the north by a stream in Goshen Hole that worked its way headward through the Bear Creek-Sixty Six Mountain gap. The Goshen Hole Area presents a number of interesting physiographic problems which are intricately related to adjacent areas and an interpretation of which will involve a consideration of most of the region traversed by the North Platte River. This is beyond the scope of the present study.

The Topographic Map

The topographic map presented as Plate 1 is mainly a compilation from the United States Geological Survey topographic sheets of the Hartville and Goshen Quadrangles. Two hundred and fifty-two square miles in the southwest portion of the area, including townships 20N-23N of Range 65W and all but a mile and a half strip along the east side of townships 20N-23N of Range 64W, were mapped by the writer and his accomplished field assistant Mr. David Bradley Cheek during the summer of 1933. The twenty foot contour lines of the section taken from the Hartville Quadrangle were interpolated from the fifty foot contour interval of that sheet.

The Geologic Map

A geologic map including an eastern strip of the Goshen Hole Area was published by Mr. G. I. Adams in his "Geology and water resources of the Patrick and Goshen Hole Quadrangles in eastern Wyoming and western Nebraska" (1902). This map was the result of reconnaissance work and illustrates only the general distribution of the formations. The northwestern corner of the area was mapped by Darton in the Hartville Folio (1903). At that early date a portion of the Laramie River vicinity was quite inaccessible and Darton mapped it as lower Miocene and missed the Whalen Fault and approximately two townships of Brule exposures immediately to the west of it. About fifteen square miles of this Brule is included in the area under consideration.

---

[1] An excellent skull and some skeletal parts of this species were collected near the town of Lingle on the north side of the river, and are now in the University of Nebraska Museum.

Most of the geologic mapping was done by the writer during the field seasons of 1930 and 1931. The southwestern portion was mapped during the summer of 1933 at which time a topographical survey was made of that vicinity. Included in the accompanying map (see Plate 2) are the Cretaceous and Yoder formations, maps of which have previously appeared in parts two and three of these Contributions. For completeness these formations have been included in the present map. Because of lack of sufficient evidence no attempt has been made to differentiate on the map the upper Harrison at the heads of Deer and Cherry Creeks from the lower Harrison. Only along the major streams, the North Platte and Laramie Rivers, has the alluvium been indicated. The major topographic features have not been shown since a topographic map (see Plate 1), drawn to the same scale, is published herewith. The towns, railroads, canals, principal roads and a few ranches are shown.

Stratigraphy

The formations considered in the present discussion, are Oligocene and Miocene in age. The oldest of these[1] is the Chadron which is the most limited in extent. It has a maximum thickness of eighty feet and is absent in many places, which results in the next succeeding formation, the Brule, resting on the Lance of the Cretaceous. The Brule, typically a flesh-colored clay, is fully represented in the area and is normally about four hundred feet in thickness. The earliest Miocene formation is the lower Harrison which rests with disconformity and in places with unconformity on the Brule. It is typically a light to gray rather unconsolidated sand with numerous sandstone concretions and some channel deposits, and has a maximum thickness of about four hundred feet. In the Deer Creek and Cherry section of the area there are approximately two hundred feet of somewhat lighter and more consolidated sands which contain an abundant amount of plant remains, and which lie above the typical lower Harrison beds. Stratigraphically the change from the lower Harrison to these strata is gradational although on the basis of the fauna they are correlative with the upper Harrison of northwestern Nebraska. The following is a detailed discussion of each of these formations.

---

[1] See part III of these "Contributions, etc." for a description of the Yoder formation,—the oldest Oligocene deposit known in the Great Plains.

Chadron. Three main exposures of the Chadron formation, having a northeast southwest trend, are present in Goshen Hole. The southeasternmost of these extends from the vicinity of Lyman, Nebraska to the northwest corner of Sixty Six Mountain, immediately west of which, across Horse Creek, is an isolated outcrop of about two square miles. The second of these exposures occurs around Lyman and Huntley, extends westward to the town of Yoder from where it continues southwestward in belt-like fashion between the Corn Creek Anticline on the northwest and the Hawk Springs Arch on the southeast. A narrow strip from Yoder to Veteran connects this belt with the northwestern and most extensive exposure, which is of continuous extent from the North Platte River up Cherry Creek southwestward, and which occupies the greater portion of the interior lowlands of the western part of Goshen Hole.

The Chadron deposits are composed of grayish, reddish and brownish green clays, which are quite sandy in places; and fine to coarse fairly unconsolidated sands and hard sandstones. The latter are most usual in the upper limits of the beds and, capping the softer clays, frequently form mesa-like prominences which are most conspicuously represented four miles southwest of the Harvard Fossil Reserve, at Red Bill Point (see Plate 3), northwest of Reichstadt's Ranch and in the Cherry Creek vicinity southeast of Doty's Ranch. Many of these, some as great as a mile in length, show the original meandering southwest-northeast course of the Chadron river with an occasional tributary. About two miles northeast of Veteran the main stream channel bends eastward and can be traced by intermittent outcrops to the south bank of the Platte, two miles southwest of Henry, Nebraska, where the upper channel sands and sandstone are more than twenty feet in thickness. Another, somewhat thinner upper channel sandstone outcrops from under the Brule clay just east of Lingle on the north side of the river. This probably is the deposit of a tributary that entered the main Chadron stream from the northwest, for it can be traced along the south side of the Platte to west of Henry where it merges with the more extensive channel sandstone.

The Chadron has a maximum thickness of eighty feet. It is commonly thinner; and in places, particularly in the southern part of the area, has been entirely removed from the underlying Lance formation before Brule deposition. Usually it rests with unconformity or disconformity upon the Lance and where the Yoder formation intervenes it is either conformable or disconformable with those beds. The Chadron deposits are easily recognizable not only by their variegated clays and green sandstones but also by the almost constant presence of titanothere remains. In general they are clearly demarked from the overlying pinkish Brule clays but in some localities the contact is not so distinct. Darton (1903, p. 3) recognized this in his comments on the Chadron southwest of Doty's ranch, and the uppermost twenty-foot sandstone in his section 1, on the basis of faunal and stratigraphic evidence, is unquestionably the same channel deposit as the one at the 4240–4265 foot level in the Harvard Fossil Reserve (see beyond under *Brule*). The contact seems least discernable, however, where the uppermost Chadron channel sandstone is absent, for there was little difference in flood plain deposition at the end of Chadron and the beginning of Brule times. Where such deposition took place the formations seem almost conformable except for the slightly darker greenish tinge of the Chadron clay which also, because of its somewhat more uniform texture and composition, weathers into a rounded hillock topography rather than the characteristic "pinnacle" topography of the Brule. A typical example of this may be seen in the S.W.¼. Sec. 36. T. 24N. R. 62W, two miles southwest of the Harvard Fossil Reserve. In this locality titanothere remains are abundant in the Chadron clays (two skulls were collected here by the Colorado Museum party).

Perhaps the best localities for studying the Chadron-Brule relationship are to be found along the south side of the North Platte River. Three miles northwest of Torrington in the S.E. ¼. Sec. 12. T. 24N. R. 62W. the following section was measured:

	Feet	Feet above Irrigation Ditch
Typical pinkish clay, somewhat sandy	22	53
Typical pinkish clay	16	37
Very sandy clay which becomes less sandy laterally	10	27
Hard gray cross-bedded sandstone with some unconsolidated sand	17	10
Brownish green clay	10	0
Concealed under irrigation ditch		

Titanothere bones occur in the seventeen-foot sandstone and this stratum is unquestionably the top of the Chadron. The succeeding ten feet of very sandy clays grade laterally into less sandy pinkish typical Brule clay which rest on greenish clays that grade into the channel sandstone.

Four miles south-southeast of this locality in the N.W.¼. Sec. 32. T. 24N. R. 61W. the following sequence occurs at the bottom of the canyon extending northwest from the Harvard quarry:

	Feet	Feet below Upper Sandstone
Dark gray consolidated "ribbon" sandstone	20–25	
Pinkish clay	5	0
Hard sandy pinkish clay	15	5
Dark gray consolidated channel sandstone	8–10	20
Green clay	1½	30
Sandy green clay	1	31½
Green clay	2½	32½
Dark clay with purplish tinge	5	35
Cream colored clay which erodes into low rounded hillocks	26	40
Pinkish clay with green streaks	3	66
Dark green and yellowish clay	2½	69
Dark green channel sandstone	7	71½
Dark green sandy clay	5	78½
Dark green clay	4½	83½
Yellowish dark green shaly clay	10½	88
Concealed by alluvium		

In this section the 8–10 foot dark gray consolidated channel sandstone marks the upper limit of the Chadron. Titanothere fragments were found at this level and the overlying pinkish clay is distinctly Brule. A mile to the northeast this channel sandstone outcrops along the Cheyenne-Torrington highway about three hundred yards south of the Union Pacific Railroad tracks. From there the channel takes a southeastward course and is concealed under the Brule for about seven miles. Immediately to the north of this tributary a lake must have existed on the flood plain during Chadron times, for in some localities a thick cherty fresh water limestone caps the Chadron clays. Such is to be found two miles south and a mile east of Torrington

(N. W.¼. Sec. 27. T. 24N. R. 61W.) where the following fairly thick section is measurable:

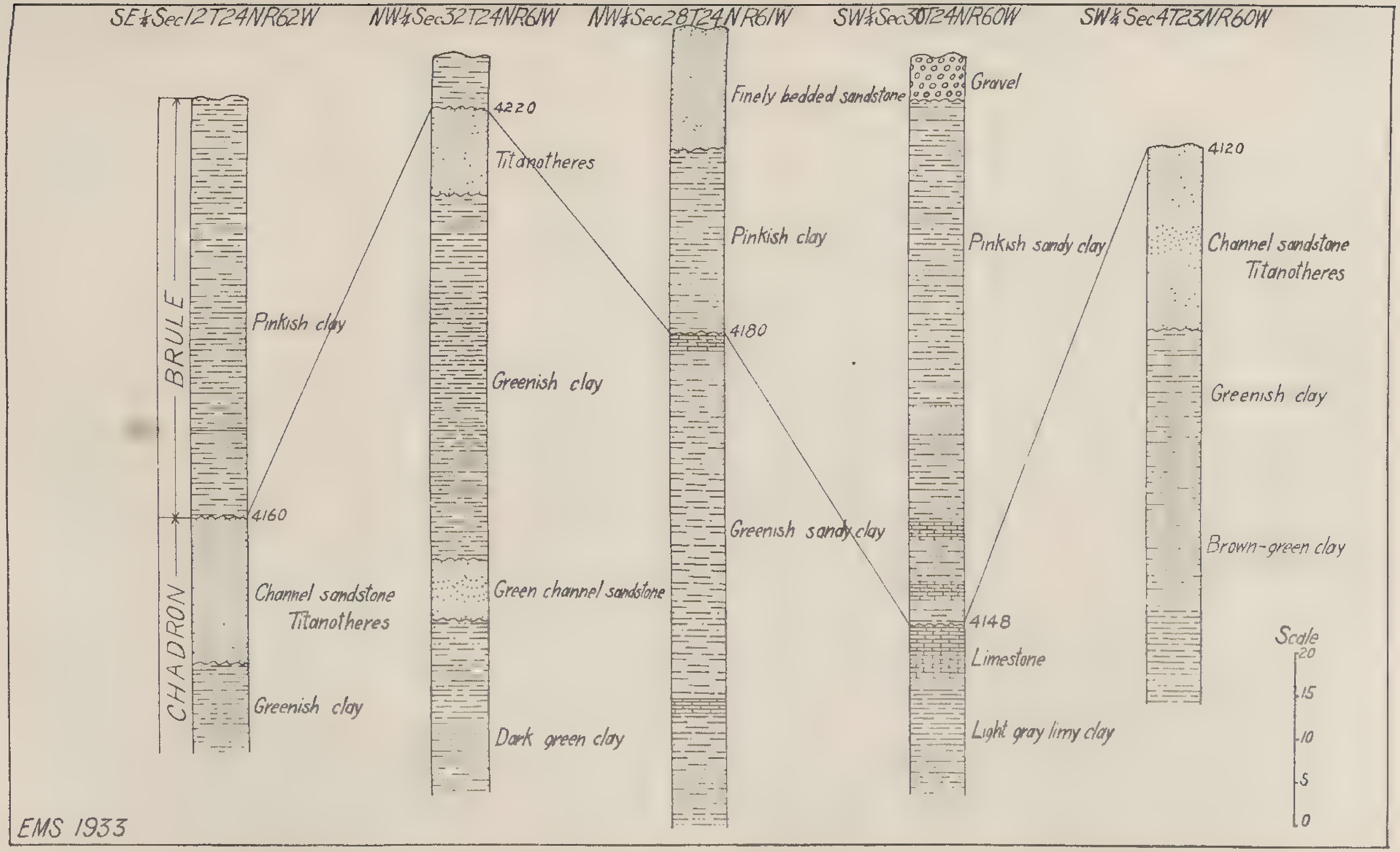
	Feet	Feet below Upper Sandstone
Gray finely bedded coarse to fine consolidated sandstone	15	
Grayish pink clays	22	0
Freshwater cherty limestone	2	22
Greenish sandy clays	40	24
Cherty freshwater limestone	2	64
Greenish sandy clay	12	66
Concealed		

Since the lower clays are markedly distinct in their greenish Chadron color, the upper two-foot limestone probably indicates the top of that formation. Three miles to the east this limestone is six feet in thickness. Up in the Brule, twenty-two feet above this limestone is a four-foot sandstone which is stratigraphically and lithologically the same as the twenty to twenty-five foot sandstone above the Chadron at the Harvard Fossil Reserve (see Figure 1). Two miles southwest of Henry, Nebraska, the upper channel is more distinct. A section in the S.W.¼. Sec. 4. T.23N. R.60W. is as follows:

	Feet	Feet above N. Platte River
Light to dark greenish gray intricately cross-bedded sands and sandstones	21	43
Hard greenish gray clay	13	30
Brown hard clay with greenish streak	30	0
Concealed by river		

The lower thirty feet of brown clay weathers to a cream color with a purplish tinge and it erodes, as well as the succeeding thirteen feet, into smooth rounded knolls. In the upper channel deposit occasional clay conglomerates are present and greenish clay lenses are frequent. Titanothere remains abound.

In Figure 1 the above described sections are graphically shown. At the locality west of Torrington the elevation of the Chadron-Brule contact is 4160 feet. Four miles southeast, at the Harvard quarry it is 4220. This slight dip to the northwest is the result of minor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NW¼Sec32T24NR61W
NW¼Sec28T24NR61W
SW¼Sec30T24NR60W
SW¼Sec4T23NR60W
BRULE
CHADRON
Pinkish clay
4160
Channel sandstone
Titanotheres
Greenish clay
4220
Titanotheres
Greenish clay
Green channel sandstone
Dark green clay
Finely bedded sandstone
Pinkish clay
4180
Greenish sandy clay
Gravel
Pinkish sandy clay
4148
Limestone
Light gray limy clay
4120
Channel sandstone
Titanotheres
Greenish clay
Brown-green clay
Scale
20
15
10
5
0
EMS 1933

Fig. 1. Columnar sections of the Chadron in the North Platte River vicinity showing lithology, correlation and Brule relationship. Schlaikjer 1933.

arching in this vicinity which is part of the Corn Creek anticlinal structure. East of the Harvard quarry at the localities given above, the elevations of the contacts are 4180, 4148 and 4120. In other words, there is a hundred-foot drop in a little more than nine miles, or a dip of approximately ten feet per mile. This is the normal inclination eastward from the Rocky Mountains of the sediments in this section of the Great Plains.

Brule. Exposures of the Brule have a greater distribution than those of any other formation in the area. The conspicuous badland topography everywhere to be seen at the base of the Goshen Hole Escarpment is developed on this formation and it constitutes the occasional table lands, such as those along the Wyoming-Nebraska state line as well as the uplands in the vicinity of Sixty Six Mountain, and immediately west and to the south of Torrington. It consists of: pinkish, flesh-colored relatively hard clays which are somewhat sandy at the base and at the top of the formation; occasional rather extensive cherty limestone lake-deposits; numerous beds of almost pure volcanic ash; and, thick channel sands, sandstones and conglomerates. It rests with disconformity (probably with conformity in places) on the Chadron, and is overlain by the lower Harrison with disconformity and unconformity. The whole of the Brule is represented in the area and has a maximum thickness of four hundred and thirty feet. Not infrequently it is much thinner for, as the result of local uplift, sometimes more than half of the beds (as at Y. B. O. Pass) have been removed before deposition of the lower Harrison began.

A generalized sequence of the most important phases of the Brule in the area is as follows:

	Feet
Pinkish, flesh colored rather hard clay becoming sandy in its upper limits	90
River channel deposit, coarse boulder conglomerate	15
Pale pinkish clay with minor channel deposits, limestone lenses and volcanic ash beds	285
Gray channel sandstone	20
Pinkish clay, sandy towards bottom at Chadron contact	20
Total thickness	430

The relationship of the Brule to the Chadron has been discussed above. The Brule clays which immediately overlie the Chadron are almost always sandy at the bottom. The lower channel sandstone is not everywhere present for it thins laterally and grades into clays. It is exposed in its maximum thickness at the Harvard Fossil Reserve and its differentiation from the upper Chadron channel is admirably shown along the road four miles north of Yoder in Sections 9 and 16. Fossils are rare in this channel deposit. Although scraps of bone and teeth could not be generically identified with certainty, they indicate the presence of a perissodactyl about the size of *Metamynodon.* For this reason and because of their stratigraphic position and relationship to the overlying strata of which the exact level is known, they are tentatively correlated with the *Metamynodon* sandstone of the South Dakota Badlands. The general trend of the Brule stream which this channel represents was from west to east and it occupied the same geographic position as did the main Chadron stream before it. It can be traced across Goshen Hole from four miles south of Doty's ranch, where it outcrops from under higher beds, eastward to north of Yoder, to the Harvard Fossil Reserve, and southeast to Rattlesnake Hill two miles west of Lyman where, in the N.W.¼. Sec. 33. T.23N. R.60W. near the bottom of a canyon, it is composed of approximately twenty-five feet of intricately cross-bedded, unconsolidated gray sands with some clay pebbles. The west-east trend of this former stream is further substantiated by the fact that in most of the cross-bedding the foreset beds are to the east.

The lithology of the next succeeding two hundred and eighty-five feet of pale, pinkish, fairly resistant clay is relatively constant throughout the area. A characteristic feature of this phase is the presence of at least three distinct beds of rather pure volcanic ash. The lower two of these beds, although lenticular, are widely distributed in the eastern part of the area and are best shown on the east side of Table Mountain. The lowest bed occurs about fifty feet above the *Metamynodon* sandstone and attains a thickness of six feet (see Plate 3, Figure 2). Twenty-seven feet higher (or seventy-seven feet above the *Metamynodon* sandstone) is the second layer which is a half-foot thick. This bed can be correlated with the two-foot layer which occurs thirty miles to the west in the western part of Goshen Hole. In this vicinity it is approximately eighty-four feet above the *Metamynodon* sandstone. Eighty feet higher (or two hundred and four feet above the Chadron) is another layer of ash only one foot thick. This is probably equivalent to the layer that is at the top of the Brule at Y.B.O. Pass where about half of that formation has been eroded away. Another feature of this middle phase of the Brule is the frequency of lenticular freshwater cherty limestone deposits. These are most significantly prominent along the low escarpment just south of Torrington, on Rattlesnake

Hill and Table Mountain, and six miles south of Red-Bill Point. In most instances the lime has been almost completely replaced by silica. Frequently these lenses are in part composed of ball-like accumulations which are probably algal in origin. More rarely, they are entirely made up of small fresh water gastropods (now being studied by Dr. William Clinch). This phase of the Brule is richly fossiliferous at certain levels (see below for description of fossil beds). Fragments of *Merycoidodon culbertsoni* and an abundance of the turtle *Stylemys nebrascensis* together with the array of forms which occur in the Harvard Fossil Reserve, show that these deposits may be unquestionably correlated with the oreodont beds of Nebraska and South Dakota.

The upper channel conglomerate is best developed eight miles southwest of Torrington in the S.E.¼. Sec. 19. T.24N. R.62W. (see Figure 1, p. 4 in Part One of these 'Contributions, etc.'). It is about fifteen feet thick and contains boulders of granite, pegmatite and gneiss as large as a foot in diameter. This undoubtedly marks the largest stream in the area towards the close of the Oligocene. Overlying this channel deposit to the northwest are ninety feet of pinkish, flesh-colored rather hard clay, the top twenty-five feet of which are quite sandy. Teeth and skeletal fragments of *Leptauchenia nitida* occur in these clays which demonstrate that they are equivalent to the *Leptauchenia* beds in other areas.

Two rich fossil deposits occur in the lower Brule formation. The stratigraphic position of these is shown in the following section measured in a canyon in the N.W.¼. Sec.32. T.24N. R.61W.

	Feet	Feet below Limestone
Alluvium (4300 foot level at top)	5	
Cherty limestone with many gastropods	2–5	
Soft clay with few bones	2–5	0
Layer of bones in clay	1–3	2–5
Light pinkish hard clay	10	5–6
Pinkish clay pebbles with fossils	1	15–16
Light pinkish clay	14	16–17
Dark gray consolidated "ribbon" sandstone	20–25	30–31
Pinkish clay	5	51–55
Hard sandy pinkish clay	15	66–70
Dark gray consolidated channel sandstone. Chadron.	8–10	

The bottom part of this section has been discussed above. The twenty to twenty-five foot *Metamynodon* channel sandstone makes a sharp bend to the north about three hundred yards west of the Field Laboratory (see Figure 2). Its lateral equivalent is about twenty feet of unconsolidated sands and clays. Above these is a one-foot fossiliferous layer which contains the rather water worn and broken remains mainly of *Subhyracodon occidentale* and *Mesohippus bairdi.* Five miles to the

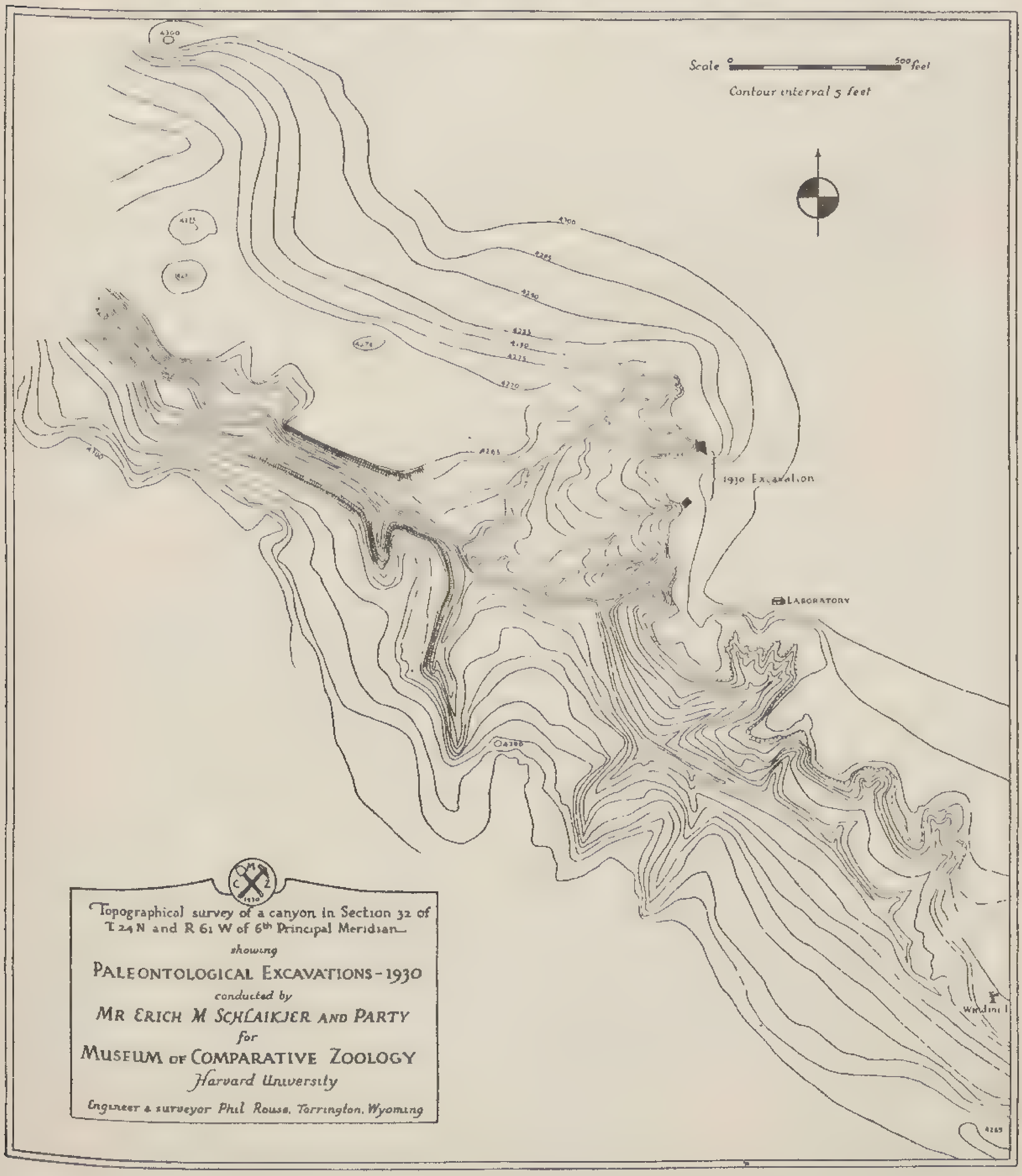
Scale 0 500 feet
Contour interval 5 feet
4300
1930 Excavation
Laboratory
Windmill
Topographical survey of a canyon in Section 32 of T 24 N and R 61 W of 6th Principal Meridian
showing
PALEONTOLOGICAL EXCAVATIONS - 1930
conducted by
MR ERICH M SCHLAIKJER AND PARTY
for
MUSEUM OF COMPARATIVE ZOOLOGY
Harvard University
Engineer & surveyor Phil Rouse, Torrington, Wyoming

FIG. 2. Map of the Harvard Fossil Reserve. Dotted line shows outcrop of fossil bed.

east in the N.W.¼. Sec. 6. T.23N. R.60W. this fossil layer is again present exactly fourteen feet above the *Metamynodon* sandstone (the latter outcrops in the northeast corner of section 6). Here the fossils, mostly the remains of *Subhyracodon*, are more abundant. The Colorado Museum party spent two field seasons collecting in this deposit.

Succeeding this lower fossil level in the above section are ten feet of light pinkish hard clay overlain by an almost solid layer of fossils from one to three feet in thickness. This is the richest and most extensive single deposit of Oligocene fossils yet recorded. It outcrops continuously for approximately a half mile (see Figure 2 and Plate 4) and contains in extraordinary abundance the remains of *Mesohippus, Pediohippus, Subhyracodon, Cynodictis, Archaeotherium, Poëbrotherium* and *Hypisodus*. Of these, the horses and rhinoceroses occur in greatest numbers. In addition, the deposit has yielded the largest collection of pre-Pleistocene fossil birds yet discovered in North America (see Wetmore, 1933). An occasional carapace of the turtle *Stylemys nebrascensis* is also present. In thirty-two cubic feet of this deposit the complete or partial remains of 288 birds, 96 horses, 18 rhinoceroses, 8 dogs, 1 camel, 1 hypertragulid, 2 entelodonts and 2 turtles were accounted for. On the basis of these figures a conservative estimate shows that there are the remains of probably between twenty and forty million individuals in this deposit! The matrix in which the bones occur is a fine pinkish clay that contains a high percentage of calcium carbonate and volcanic ash. Throughout a large part of the deposit the clay is comparatively hard and is somewhat difficult to work. At the south excavation, however, (see Figure 2) the bones occur in soft clay. This excavation is located in about the center of the deposit. Above the bone-bearing stratum is a two to five-foot layer of soft clay which contains occasional bird and *Cynodictis* remains. Above this is a two to five-foot bed of white, cherty limestone, the upper limits of which are rich in the shells of small freshwater gastropods. This limestone is thickest, as is also the underlying fossil deposit, where the south excavation is located. From there it thins to the south and to the north. It continues eastward uninterruptedly for about three miles and to the west for an equal distance,—thinning, of course, in those directions. This limestone undoubtedly represents an accumulation in a fresh-water lake which must have been at least three miles wide and six to eight miles long. In its thinner portions plant remains occur in remarkable abundance in the form of roots and branches that vary from a quarter of an inch to two inches in diameter.

In this vicinity marsh and lake conditions prevailed throughout the early part of the Brule. Here animals lived in prolific numbers. The amassment of their remains is, however, somewhat puzzling. All of the material is disarticulated, and many of the bones are broken, most of which probably occurred before fossilization. Since hardly a single water-worn bone has been found, it is not likely that this concentration is due to severe stream action. Probably the bones of those animals that died along the shores, as well as on the actual mud flats of this lake when its waters were more restricted during the drier seasons, were washed into the deeper portions during times of freshets and floods and thereby accumulated to form this rich deposit.

The main part of this fossil deposit occurs in the south half of the N.W.¼. Sec. 32. T.24N. R.61W. which tract of land has been purchased by Harvard College and is designated as the *Harvard Fossil Reserve.*

Lower Harrison. This formation constitutes the high upland table lands of the area and is exposed principally on Sixty Six Mountain (see Plate 7), Bear Creek Mountain, in the southwestern corner of the area and in the vicinity of Deer and Six Mile Creeks south of Old Fort Laramie. Its maximum thickness is approximately four hundred feet and it is mainly composed of light to dark gray unconsolidated sand and sandstones in the form of channels and concretions. (See Plate 6, Figure 2). This lithologic character is particularly true for the lower three hundred feet which are rather abundantly fossiliferous. The upper one hundred feet is usually lighter in color, is less concretionary and is almost barren of fossils.

The lower Harrison formation rests with disconformity and unconformity on the Brule and its lowest limits are generally marked by channel deposits. The Brule-lower Harrison contact is widely shown and its interpretation presents one of the most interesting stratigraphic problems in the area. Considering the relationship between these two formations, an outstanding feature is that the lower channel phase of the Harrison becomes more and more dominant from Sixty Six and Bear Creek Mountains northward to Y.B.O. Pass, Box Elder Creek, Wilson's Ranch, Cherry Creek and along the northern part of the Goshen Hole Escarpment. A series of sections covering these localities are given below.

The following sequence was measured at the east end of Sixty Six Mountain at the Nebraska-Wyoming State line in the S.E.¼. Sec. 3. T.20N. R.60W. (See Figure 3).

	Feet
Gray sand	15
Gray sands with pipy concretions	32
Volcanic ash	1½
Gray sands, slightly clayey with pipy concretions	74
Volcanic ash	1½
Finely bedded grayish brown sand with occasional pipy concretions	10½
Volcanic ash	4
Finely bedded gray sand	3
Gray to pinkish sandy clay (this marks the top of the Brule; elevation 4720)	16½
Pink sandy clay	10+

The sixteen and a half feet of gray to pinkish sandy clay probably belongs to the Brule. It is gradational into the typical pink sandy clay below and is sharply differentiated by a disconformity from the overlying gray sands of the Harrison. Four miles north at Eagle's Nest a duplicate sequence occurs except that the volcanic ash layers are thinner and the pipy concretions are less dominant. Five miles to the northeast at Signal Butte in Nebraska, the lowermost Harrison is composed of rather well stratified sands with only very thin sandstone layers. At the northwest end of Sixty Six Mountain in the N.E.¼. Sec. 7. T.20N. R.60W. the typical Brule clay is overlain by a three-foot clay conglomerate above which are nineteen feet of clay sands that grade upward into the gray sands with pipy concretions. In the S.W.¼. Sec. 36. T.20N. R.62W. at the east end of Bear Creek Mountain the following section was measured. (See Figure 3).

	Feet
Light gray sands few sandstone lenses. No fossils found	100+
Gray sands with pipy concretions	128
Rather compact gray sands with many fossils such as *Promerycochoerus, Nanotragulus, Mesocyon,* etc.	6
Gray sands with many pipy concretions and *Daemonelix* in places	77
Gray sands finely bedded and in places with aeolian cross-bedding	48
Gray sands with pipy concretions. *Stenomylus hitchcocki* at top	16
Volcanic ash	1
Gray sands with pipy concretions	7
Sandy clay with 6–10 foot layer of clay conglomerate at top	42
Typical fine grained Brule clay, somewhat sandy	50+

There is an irregular contact at places between the forty-two-foot layer of sandy clay and the typical Brule clay beneath. At other places the two seem conformable. The six to ten-foot conglomerate material is reworked Brule clay and is clearly demarked from the overlying gray Harrison sands. This is the only locality where *Daemonelix* specimens were observed. The occurrence of these together with the little camel *Stenomylus hitchcocki* proves conclusively that these lower Miocene beds are lower Harrison in age. The upper part of the one hundred and twenty-eight-foot bed is sparsely fossiliferous and the top one hundred feet are decidedly lighter in color with only a few sandstone lenses and apparently no fossils. These upper light colored beds have a rather uniform distribution throughout the area and are present wherever a thick section of the Miocene occurs, as at Cherry Creek and near Old Fort Laramie where the Miocene has been down faulted just to the east of the Whalen Fault and the higher levels have not been removed by erosion. Also, they always seem to be gradational into the gray concretionary beds below. For these reasons I am inclined to include them, provisionally at least, in the lower Harrison.

At the west end of Bear Creek Mountain the above section is duplicated, except that resting on the Brule clay is a foot and a half of clay conglomerate succeeded by thirteen feet of sandy clay above which is a two-foot channel sandstone that is overlain by another foot and a half of clay conglomerates. Above the latter are sixteen feet of somewhat clayish sand that grades upward into gray concretionary sands (see Figure 3). These thirty-four feet of material probably represent the forty-two-foot lower bed in the section at the east end of the mountain.

Immediately north of Y.B.O. Pass in the N.W.¼. Sec. 5. T.21N. R.64W. the Brule-Miocene sequence is as follows:

	Feet
Gray sands, numerous pipy concretions, some aeolian cross-bedding...	45+
Rather consolidated gray sands	5
Gray sands with numerous pipy concretions	36
Light to dark gray sands with many pipy concretions	69
Hard gray consolidated sands	10
Coarse channel sands and boulders	5
Fairly coarse gray sands	10
Pinkish Brule clay (elevation of contact 4930)	20
Volcanic ash	2
Pinkish Brule clay	60+

Here the Brule is only about two hundred feet thick,— approximately half of its normal thickness. The contact with the Miocene is clearly at the bottom of the first ten-foot layer of rather coarse sands. Above these the five-foot coarse channel sands, with boulders of gneiss, granite, quartzite, etc., become less clastic at the top and grade upward into the overlying rather consolidated sands. The remainder of the section presents no distinctive features. Eight miles to the northwest in the N.E.¼. Sec. 6. T.22N. R.65W. (three-quarters of a mile northeast of Wilson's Ranch), the channel phase immediately above the Brule is much thicker. In this locality the Brule is represented by practically its maximum thickness (elevation of contact with the Miocene is 5090 feet) and is rather sandy in its upper limits. Following the Brule is a coarse channel conglomerate twenty feet in thickness which is separated by a ten-foot bed of sandy clay from the overlying twenty-six feet of coarse channel conglomerates and sands. (See Plate 5, Figure 2). These channel beds evidently represent the course of the major stream in this area in late Oligocene and early Miocene times. They can be traced continually southwestward to the escarpments along Chugwater Creek where they sometimes attain a thickness of one hundred feet or more. Five miles due north of Wilson's Ranch and from there northeastward to Cherry Creek the lowermost Miocene sediments are fairly well bedded fine sands with thin sandstone layers and small globular sandstone concretions as well as occasional beds of somewhat more clastic materials,— typical flood plain and alluvial flat deposits. Two miles north of Doty's Ranch the channel beds again appear and are from thirty to fifty feet thick. They thin westward and eastward. In the N.W.¼. Sec. 36. T.25N. R.63W. the deposit is thinner and less clastic. Its unconformable position on the Brule is shown in Plate 6, Figure 1. In this locality the full width,— almost four miles, of this Miocene river bed can be seen.

Another channel sandstone and conglomerate, although of more limited extent, occurs in the northwestern corner of the area where it has been faulted to the surface and is exposed along the Laramie River and just south of Whalen Dam on the North Platte (see Plates 8 and 9). It too has a southwest-northeast trend and can be traced for a number of miles eastward on the north side of the North Platte River.

An analysis of the above sections, several of which are illustrated in figure 3, reveals the following facts concerning the late Oligocene and early Miocene in the area:

1. Where the Brule is fully represented it becomes more and more sandy in its upper limits. This is probably the result of gradual uplift in the Rocky Mountains towards the close of the Oligocene which resulted in the transportation of more clastic sediments farther out onto the plains.

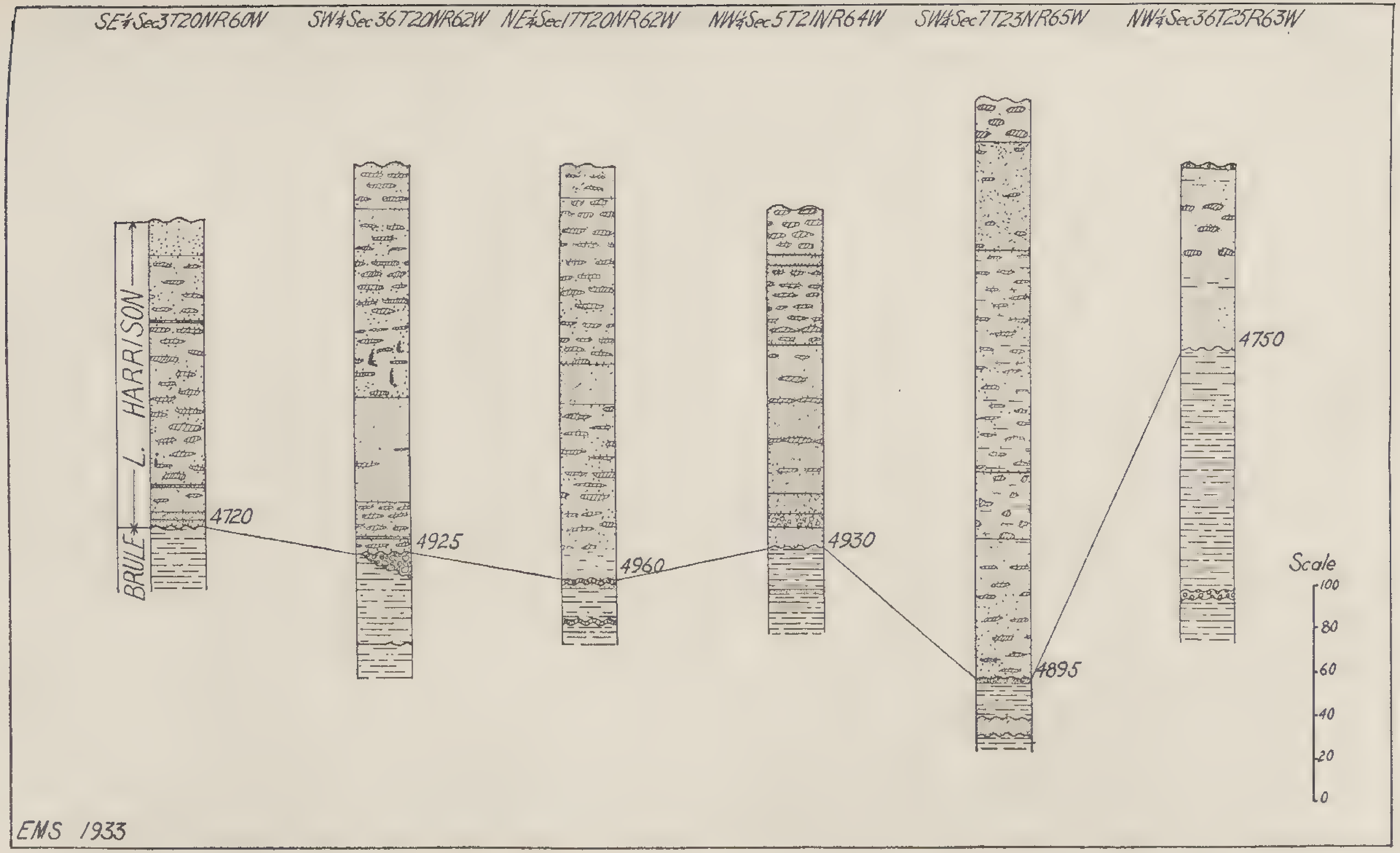
SE¼Sec3T20NR60W
SW¼Sec36T20NR62W
NE¼Sec17T20NR62W
NW¼Sec5T21NR64W
SW¼Sec7T23NR65W
NW¼Sec36T25R63W
L. HARRISON
BRULE
4720
4925
4960
4930
4895
4750
Scale
100
80
60
40
20
0
EMS 1933

Fig. 3. Columnar sections along the Goshen Hole Escarpment showing Brule-lower Harrison relationship, lithology and correlation. Schlaikjer 1933.

2. The end of the Oligocene and the beginning of the Miocene were marked by rejuvenation of the drainage system caused by major uplift of the mountains to the west. This is shown by erosion and redeposition of Brule clay, the presence of channel conglomerates, the numerous volcanic ash layers and the clastic nature of the Miocene sediments.

3. The thick channel deposits in the northwestern portion of the area indicate the position of the main early Miocene river which had a southwest-northeast trend.

4. The thin layer of coarse sands with some conglomerate material at Y.B.O. Pass are the deposits of a minor tributary to this major stream.

5. The clay conglomerates at the Bear Creek Mountain and Sixty Six Mountain localities represent relatively rapid accumulations formed by small streams. The material may have been derived, in part at least, from an erosion of the Brule in the Y.B.O. Pass vicinity where there was local uplift at that time.

It can be concluded therefore, that the channel deposits at the base of the Miocene are synchronous.

Upper Harrison. At the heads of Deer and Cherry Creeks there is a series of light to dark gray sands and sandstones which contain some lenticular beds of clay and which, at certain levels are made up of more than fifty percent of plant remains. The total thickness of these beds is between one and three hundred feet. There is no extensive clear demarcation between them and the upper levels of the lower Harrison. About four hundred feet above the Brule-lower Harrison contact, however, there is a fairly abrupt change to coarser sands and sandstones and to numerous but thin clay beds. This zone probably marks the change from lower to upper Harrison. A hundred feet higher good specimens (see beyond under Palaeontology) of *Parahippus wyomingensis*, *Merychyus minimus*, *Oxydactylus* and *Palaeocastor* were collected. The nearest affinities of these forms occur in the upper Harrison of northwestern Nebraska. For these stratigraphic and palaeontological reasons I am considering, tentatively at least, the upper three hundred of the seven hundred feet of Miocene in this locality as upper Harrison in age.

Correlation

Chadron. On the basis of our present knowledge of the fauna from this formation in the area and taking into consideration its stratigraphy, it seems identical with the Chadron in other areas, such as Nebraska and South Dakota.

Brule. The reasons for correlating the lower channel phase of the Brule with the *Metamynodon* sandstone of South Dakota have been cited above. The large assemblage of species collected from the fossil layer, thirty feet higher, at the Harvard Fossil Reserve show without question that that level is equivalent to the upper nodular layer of the middle oreodont beds in the Big Badlands. Species which are distinctive of this level are *Mesohippus barbouri* and *M. obliquidens;* and species most commonly abundant at this level are *Cynodictis gregarius, Subhyracodon occidentale* and *Archaeotherium mortoni.* In addition, the only other remains of *Bathornis celeripes* found outside of the Harvard quarry were collected from the middle oreodont beds north of Harrison, Nebraska (see Wetmore, 1933, p. 308). In the upper limits of the Brule, *Leptauchenia nitida* and occasionally *Palaeolagus agapetillus* are found. These forms definitely indicate the presence of the *Leptauchenia* beds. The upper channel deposit of the Brule, although no fossils have been found in it, may be the correlate of the *Protoceras* sandstone level of the Big Badlands. It certainly occurs at the correct stratigraphic position. It seems, therefore, that the entire Brule formation is represented in the Goshen Hole Area.

Lower Harrison. The name Arikaree (spelled Arickaree) was first applied by F. W. Cragin (1896, p. 52) to a series of "Light-colored, olive, yellowish and brownish-gray shales" exposed on the Arickaree River in Colorado and Kansas which he referred to "the lower part of the Fox Hills division" of the Cretaceous. In 1898 G. I. Adams (p. 27) referred these Arikaree shales to the upper part of the Pierre. Darton in 1899 (p. 735) used the name Arikaree,— apparently not knowing that it was preoccupied, for a part of the lower Miocene, including everything below Ogallala of the Pliocene down to the Gering beds of southeastern Wyoming and western Nebraska, which is composed of "a series of sands of gray color everywhere characterized by layers of dark gray concretions which often have tabular form." J. B. Hatcher (1902, pp. 116–117) divided Darton's Arikaree into the Monroe Creek, the Harrison and the Nebraska beds of Scott. (The term *Nebraska Beds* is no longer in use. It is a general term that included what are now known as the upper Harrison and the Valentine). In 1904 Matthew and Gidley gave the name Rosebud beds to the lower Miocene of southwestern South Dakota and northern Nebraska. In 1907 Dr. Matthew recognized two divisions to the Rosebud and rightfully correlated it with the Harrison. Since that time a number of the same species, as found in the lower Rosebud, have been recognized in the lower Miocene,— unquestionably lower Harrison, of other areas (Spanish Diggings — Lusk localities north of Goshen Holé). The name *Gering formation* was given by Darton (1899 pp. 735–736) to a series of channel deposits at the base of the Arikaree in the Scotts Bluff vicinity south of the North Platte River. In 1899 Darton stated that, "the character of the deposits and the *abrupt* change from the typical Arikaree formation have afforded a basis for the discrimination of this formation." In the Scotts Bluff Folio (1902) Darton presented a further study of the Gering and wrote (pp. 2–3), "It is separated from the Brule clay by a distinct erosional unconformity, but *appears to merge upward into the Arikaree formation through a few feet of passage beds.*" I have inspected the Gering formation at the type locality south of Gering, Nebraska and have made a preliminary study of it from that locality westward to Wyoming. It appears to be nothing more than an exaggerated eastward extension of the same conditions that prevail at the base of the lower Harrison in the Goshen Hole Area. In other words, the Gering represents only a local phase of the lower Harrison and ought not to be regarded as a separate formation any more than the *Metamynodon* or *Protoceras* channel phases of the Brule should be regarded as distinct formations of the Oligocene. The fauna of the "Gering" is certainly not well known. In the northern part of Goshen Hole approximately fifty feet below the "Gering" channel beds or fifteen feet above the Brule contact the small canid *Nothocyon leptodus* sp. nov. was collected. While this individual represents a new species it is far more closely related to *Nothocyon annectens* of the lower Harrison than to any other known species. On the west end of Bear Creek Mountain *Cyclopidius densa,* a lower Harrison species, was found twelve feet above and another specimen forty feet above the Brule contact. On the east end of Bear Creek Mountain the little camel *Stenomylus hitchcocki* was collected twenty-four feet above the Brule contact. Previously this species has been recorded only from the lower Harrison formation four and a half miles east of Agate, Nebraska. When a fairly complete fauna of the "Gering" is known, however, that it will be somewhat distinct,— as is every "river fauna" (as the *Metamynodon* and *Protoceras* faunas of the Oligocene) is to be expected.

A complete list of species from the lowermost Miocene of the Goshen Hole Area is as follows:

Palaeolagus hypsodus sp. nov.
Hypolagus primitivus sp. nov.
Archaeolagus ennisianus (Cope)
Palaeocastor sp.
Sciurus sp.
Nothocyon leptodus sp. nov.
Mesocyon hortulirosae sp. nov.
Plionictis sanguinarius[1] Loomis
Miohippus sp.
Parahippus ?pristinus Osborn
Hypohippus avus sp. nov.
Menoceras cooki (Peterson)
Dinohyus minimus sp. nov.
Cyclopidius heterodon Cope
Cyclopidius densa (Loomis)
Cyclopidius simus Cope
Cyclopidius lullianus[2] Thorpe
Leptauchenia minora sp. nov.
Merychus harrisonensis Peterson
Eporeodon cheeki Schlaikjer
Mesoreodon chelonyx Scott
Mesoreodon megalodon Peterson
Promerycochoerus loomisi Schlaikjer
Promerycochoerus hatcheri Douglass
Miotylopus bathygnathus gen. et sp. nov.
Stenomylus hitchcocki Loomis
Protomeryx sp.
Nanotragulus intermedius sp. nov.

Of the forms that are not new, and excluding *Plionictis sanguinarius*, *Eporeodon cheeki* and *Promerycochoerus loomisi* which have been recorded only from the Goshen Hole Area, three species,— in addition to *Daemonelix*, are distinctive of the Harrison. They are *Menoceras cooki*, *Merychyus harrisonensis* and *Stenomylus hitchcocki*. One of these, *Menoceras cooki* together with *Cyclopidius densa* (also recorded from the lower Harrison southwest of Chadron, Nebraska), *Cyclopidius lullianus* and *Mesoreodon megalodon* occur in the lowermost Miocene beds in the "Spanish Diggings"— Lusk, Wyoming area immediately to the north of Goshen Hole. *Mesoreodon megalodon* was first recorded from the Monroe Creek beds. Four lower Deep River (Fort Logan) species, all oreodonts, are present,— *Cyclopidius heterodon*, *C. simus*, *Mesoreodon chelonyx* and *Promerycochoerus hatcheri*. One Rosebud species, *Parahippus ?pristinus*, and one John Day species, *Archaeolagus ennisianus* are also in the list. Of the new species, having close affinity with lower Miocene forms from other areas, *Mesocyon hortulirosae* is nearest *M. josephi* of the John Day while *Nothocyon leptodus*, *Dinohyus minimus* and *Nanotragulus intermedius* have their closest relationships with typical lower Harrison members. It is obvious, therefore, that on the basis of stratigraphic and faunal evidence the lowermost Miocene beds in the Goshen Hole Area are lower Harrison in age. It is of importance that four lower Deep River species are present in the fauna. This is additional evidence for correlating those beds with the lower Harrison. That a number of the Goshen Hole species also occur in the "Spanish Diggings"— Lusk area is not surprising for those beds can be traced eastward into the lower Harrison formation of western Nebraska. The occurrence of *Parahippus ?pristinus* and *Mesoreodon megalodon* in the lower Harrison of Goshen Hole is significant. To find a lower Rosebud species and a Monroe Creek species in the same beds is not unusual. While the fauna of the Monroe Creek is very scanty it is hardly separable from that of the lower Rosebud. This together with the stratigraphic occurrence, leaves little doubt that the two are contemporaneous deposits. Likewise, the occurrence of Rosebud species in the lower Harrison is not surprising. As early as 1907, Dr. Matthew because of faunal similarities correlated the Rosebud with the Harrison. I have traced the lower Miocene along an almost continuous series of exposures from the Rosebud-Pineridge district of South Dakota southwestward across Nebraska, via Chadron and Agate, into the Scotts Bluff-Goshen Hole areas and I have been unable to discern where the lower Rosebud ends and the lower Harrison begins. I, therefore, can see no reason for separating into two distinct formations a synchronous deposit which is faunally and stratigraphically variable only in so far as was governed by local environmental and depositional conditions. The name *Arikaree* should not be resurrected for this formation since it is preoccupied, since it is too inclusive as originally defined and since it is obsolete. *Harrison* seems most appropriate not only because it is perhaps more widely used than *Rosebud* but also because it has priority.

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[1] Found by Dr. Loomis on Sixty Six Mountain, lowermost Miocene.

[2] A skeleton, referred to this species, was collected from the lowermost Miocene on Sixty Six Mountain, by Dr. Loomis.

Structure

The general structural features of the Goshen Hole Area together with a description of the most important structures within Goshen Hole itself have been considered previously (part II, pp. 52–53). There is evidence that the area has probably been subjected to at least five diastrophic movements since late Cretaceous times. Two of these, one at the close of the Fox Hills and the other between the close of the Cretaceous and the beginning of the Oligocene have been discussed (see part II, pp. 50–53 and part III, p. 74). As was stated above, the Chadron formation is absent in a large part of the southern portion of Goshen Hole and in those localities the Brule rests directly on the Lance. This is probably the result of uplift and erosion in that vicinity because of the following reasons: 1. The Chadron formation has a relatively uniform thickness and a wide geographic distribution. 2. The Brule-Chadron contact locally presents a fairly pronounced disconformity. 3. The fine grained Chadron clays do not include an appreciable amount of the coarse unconsolidated sands of the Lance, on which they rest, which would have been the case had they been deposited in erosional lows.

Local uplift at the end of Brule times is significantly shown in the area. At Y.B.O. Pass approximately two hundred feet of that formation were removed by erosion before the overlying Miocene strata were deposited. To the northwest and to the southeast the Brule again attains its full thickness. Moreover, additional evidence of disturbance previous to the Miocene is shown by the presence of strong dips, due in part perhaps to slumping, as great as 43° (see Plate 5, Figure 1) at Fox Creek Gap. This tilting does not occur in the Miocene above. The occurrence of an occasional fissure in the Brule, down into which Miocene sands and boulders of Brule clay have been injected, seems to show that severe earthquakes took place concomitant with this uplift. The largest of these fissures having a maximum width of three feet, crosses the northwest corner of the Harvard Fossil Reserve. It is of interest to note that this fissure has a strike parallel with the strike of the Corn Creek Anticline and occupies a position which would be on the crest of that structure were its surface expression continued northeastward. These fissures cannot be regarded as shrinkage cracks resulting from the drying out of the clay because they are not numerous (only three have been observed), they are too large and they have the same orientation,— southwest-northeast.

The major diastrophism recorded in the area occurred after the Miocene when the whole area was broadly upwarped or domed. This is shown by the fact that everywhere along the Goshen Hole escarpment the strata have a one to three degree dip away from the interior lowlands. Also, throughout the area there is an intricate system of minor faults and fissures which parallels a major fault zone to the northwest. On the south side of the North Platte River about three miles southeast of the Whalen Dam there is a large normal fault which at this place has a strike N. 70° E. and a dip 61° S.SE. (See Plates 8 and 9). Behind this fault the upper Brule clay, capped by the Brule-Miocene conglomerate, has been brought to the surface. On the east side, the uppermost beds of the lower Harrison occur on the Laramie River three miles south at a level four hundred feet below the top of the Brule which means a throw of seven hundred feet. This fault, to which the name *Whalen Fault* is given, extends northeastward some ten to fifteen miles and it was traced southwest to where it again crosses the Laramie River but in which locality it is more of a crushed zone than a single fault. Many minor faults and fissures are present in this faulted zone. For example in Sec. 31 T. 26N. E. 65W. there is a vertical fault with a displacement of not more than fifteen feet. In the immediate vicinity of this is a network of chalcedony veins which probably represents deposition of silica in fissures from cold solution since the silica penetrates the walls of these fissures only a short distance. To the southeast of the Whalen Fault the strata are also considerably fractured. This minor faulting, along with the reasonably steep dips (in Sec. 36. T. 26N. R. 65W. the beds dip as much as 7° northwest) has probably had much to do with determining the southwest-northeast trend of Six Mile and Deer Creeks and the head portion of Cherry Creek.

On the Laramie River in front of the Whalen Fault the elevation of the top of the lower Harrison is 4250 feet. Assuming that the formations in this locality have thicknesses which are normal for them in the area, there are 1580 feet of sediment above the Pierre shales. In other words the elevation of these shales is 2670 feet or at least 1730 feet lower than they are along Corn Creek over in Goshen Hole. This is in contrast to the very gentle inclination (about ten feet per mile) of the beds southeastward from the vicinity of the Corn Creek Anticline (see Plate 7).

PALAEONTOLOGY

As stated previously, the turtle *Stylemys nebrascensis* occurs abundantly throughout the Brule. Another form, which has been identified by Dr. Theodore White, as *Testudo peragrans* occurs with equal abundance in the lower Harrison. More than a dozen specimens of this species were collected. A large individual (over two feet in length), having a pathological abnormality in the carapace, is shown in Plate 10.

Dr. Alexander Wetmore of the National Museum has studied the large collection of fossil bird bones collected from the Harvard Fossil Reserve and has described several new forms of which the following is a list:

Order FALCONIFORMES
    Family ACCIPITRIDAE
        Subfamily BUTEONINAE
            Buteo antecursor

Order GRUIFORMES
  Suborder CARIAMAE
    Family BATHORNITHIDAE
      Bathornis celeripes
      Bathornis cursor

In the very large collection of fossil mammals from the Chadron, Brule and Harrison formations, forty-two species are represented.[1] Of these, thirteen species and two genera are new and several unquestionably new forms are present in the material which has not yet been prepared for study. The following is a complete faunal list of the mammals:

Order RODENTIA
  Suborder DUPLICIDENTATA
    Family LEPORIDAE
      Palaeolagus hypsodus sp. nov.
      Palaeolagus agapetillus Cope
      Hypolagus primitivus sp. nov.
      Archaeolagus ennisianus (Cope)
  Suborder SIMPLICIDENTATA
    Family CASTORIDAE
      Palaeocastor sp.
    Family SCIURIDAE
      Sciurus sp.

Order CARNIVORA
  Suborder FISSIPEDIA
    Family CANIDAE
      Cynodictis gregarius (Cope)
      Nothocyon leptodus sp. nov.
      Mesocyon hortulirosae sp. nov.

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[1] Not including *Apternodus gregoryi* from the middle Oligocene which has been fully described in Part I of these "Contributions, etc."

Order PERISSODACTYLA
  - Superfamily EQUOIDEA
    - Family EQUIDAE
      - *Pediohippus antiquus* gen. et sp. nov.
      - *Mesohippus barbouri* Schlaikjer
      - *Mesohippus obliquidens* Osborn
      - *Miohippus* sp.
      - *Parahippus ?pristinus* Osborn
      - *Parahippus wyomingensis* sp. nov.
      - *Hypohippus avus* sp. nov.
  - Superfamily TAPIROIDEA
    - Family TAPIRIDAE
      - *Genus and species undescribed*
  - Superfamily BRONTOTHERIOIDEA
    - Family BRONTOTHERIIDAE
      - *Allops cf. marshi* (Osborn)
  - Superfamily RHINOCEROTOIDEA
    - Family RHINOCEROTIDAE
      - *Subhyracodon occidentale* Leidy
      - *Menoceras cooki* (Peterson)

Order ARTIODACTYLA
  - Suborder BUNODONTA
    - Superfamily DICHOBUNOIDEA
      - Family ENTELODONTIDAE
        - *Archaeotherium palustris* sp. nov.
        - *Archaeotherium mortoni* Leidy
        - *Dinohyus minimus* sp. nov.

Suborder ANCODONTA
  Superfamily AGRIOCHOEROIDEA
    Family OREODONTIDAE
      Cyclopidius heterodon Cope
      Cyclopidius densa (Loomis)
      Leptauchenia minora sp. nov.
      Merychyus harrisonensis Peterson
      Merychyus minimus Peterson
      Eporeodon cheeki Schlaikjer
      Mesoreodon chelonyx Scott
      Mesoreodon scotti Schlaikjer
      Mesoreodon megalodon Peterson
      Merycoidodon culbertsoni Leidy
      Promerycochoerus loomisi Schlaikjer
      Promerycochoerus hatcheri Douglass
Suborder TYLOPODA
  Superfamily CAMELOIDEA
    Family CAMELIDAE
      Miotylopus bathygnathus gen. et sp. nov.
      Stenomylus hitchcocki Loomis
      Protomeryx sp.
      Oxydactylus sp.
Suborder PECORA
  Superfamily TRAGULOIDEA
    Family HYPERTRAGULIDAE
      Nanotragulus intermedius sp. nov.
      Hypisodus alacer Troxell
      Leptomeryx evansi Leidy
      Leptotragulus ultimus sp. nov.

Order RODENTIA

Suborder DUPLICIDENTATA

Family LEPORIDAE

PALAEOLAGUS HYPSODUS[1] sp. nov.

Type. A right maxilla with P^3–M^2, M. C. Z. No. 2,889. Collected by Erich M. Schlaikjer, 1930.

Horizon and locality. Lower Miocene. Lower Harrison formation, approximately 150 feet above the Brule-lower Harrison contact. N. W. ¼. Sec. 21. T. 20N. R. 62W. Goshen County, Wyoming.

Specific characters. About the size of *P. agapetillus.* Teeth very hypsodont. P^3 almost quadrate in cross-section. P^4–M^2 oval in outline. Re-entrant angles more compressed and proportionately more extensive than in the other species. Teeth almost entirely covered with cement. (See Fig. 4).

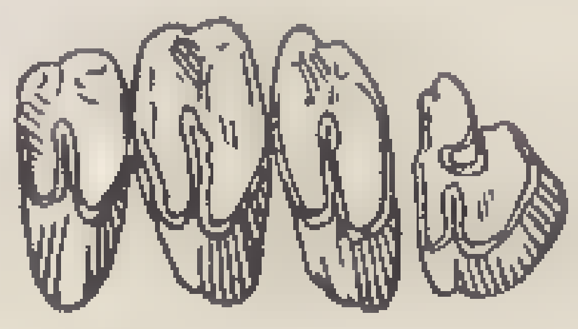

FIG. 4. *Palaeolagus hypsodus.* Type. Superior view of P^3–M^2. Twice natural size. Drawn by Helen Ziska.

Discussion. P. hypsodus is the last known member of this typically Oligocene genus. In all of the characters listed above it has progressed somewhat over the "typical" *Palaeolagus* of the Oligocene, but is not nearly as advanced as *Hypolagus* which was existing at the same time. This is another striking example of a primitive form, representative of an ancestral stage existing, as a living fossil, along with a more advanced type. *Palaeolagus* probably became extinct at the close of the lower Miocene.

Measurements

	mm.
Distance from P^3–M^2	7.8
Length of P^3	2.1
Width of P^3	2.5
Length of P^4	1.8
Width of P^4	3.0
Length of M^1	1.8
Width of M^1	2.9
Length of M^2	1.8
Width of M^2	2.6

From the Greek *υψι*, tall; and *οδους*, tooth.

PALAEOLAGUS AGAPETILLUS Cope

Material. A left maxillary with P^2–M^2 and the root of M^3, M. C. Z. No. 2,890. Collected by Erich M. Schlaikjer, 1930.

Horizon and locality. Upper Oligocene. Brule formation, *Leptauchenia* beds. Lone Tree Canyon. Goshen County, Wyoming.

Discussion. This specimen compares very closely with the neotype skull of this species described by Dr. Matthew (1902, pp. 307–308) from the *Leptauchenia* beds of Logan County, Colorado, except that P^4 is of slightly greater antero-posterior dimension. P^2 and M^3 are greatly reduced and the internal grooves of the premolars and molars are covered with cement in both specimens.

The species *P. agapetillus* was based by Professor Cope on a lower jaw. When Dr. Matthew referred the above mentioned skull, as well as a number of jaw fragments, to this species he recognized that the material represented a species distinct from *P. hydeni* but stated (p. 308) "Whether the type of *P. agapetillus* is properly referred to it, I am unable to decide; but leave it provisionally." The status of *P. agapetillus* is of no particular concern in this connection and at present must remain problematical. In dental evolution this species seems the most advanced of the *P. temnodon-hydeni-agapetillus* group which, as suggested by Dr. Matthew (1903, p. 218), represents a phylum of *Palaeolagus* with the internal median fold of enamel on the superior premolar-molar series more deeply incised than in the *P. brachyodon-turgidus-intermedius* phylum.

HYPOLAGUS PRIMITIVUS sp. nov.

Type. The orbital region of a skull with the right P^2–M^3, M. C. Z. No. 2,887. Collected by Erich M. Schlaikjer, 1933.

Horizon and locality. Lower Miocene. Lower Harrison formation, approximately 150 feet above the Brule-lower Harrison contact. S.E.¼. Sec. 15. T.21N. R. 64W. Goshen County, Wyoming.

Specific characters. Slightly smaller than *H. vetus* (Kellogg). Crenulations of re-entrant angle less developed. P^3 proportionately long (antero-posteriorly) and with crescent present. M^3 relatively very much reduced. Skull relatively deep with the anterior of orbit gently curved and the orbit proportionately large. (See Figure 5).

Discussion. P^2 is rather small and possesses a shallow but very compressed anterior groove. P^2 has the greatest antero-posterior dimension of any tooth in the series. In the center of the crown is the remnant of a rather large crescent. There is a shallow internal groove which becomes less pronounced farther down the crown. At the postero-external corner of the tooth there is a small rootlet. A similar remnant is present on the antero-external corner of P^4 and of M^1 on which tooth it amounts to only a tiny short crest. No crescent is present on P^4 and all that remains of the re-entrant angle is a faint internal groove. Even this groove is absent on M^1 although near the center of the occlusial surface is a narrow portion of the crenulated re-entrant angle. The re-entrant angle is best preserved on M^2. It extends at least half way across the crown and crenulations are fairly well developed. Through wear the internal groove has become separated from the more external part of the re-entrant angle but not as much so as in M^1. M^3 is relatively much reduced and the crown is simple in pattern. There is no cement on any of the teeth.

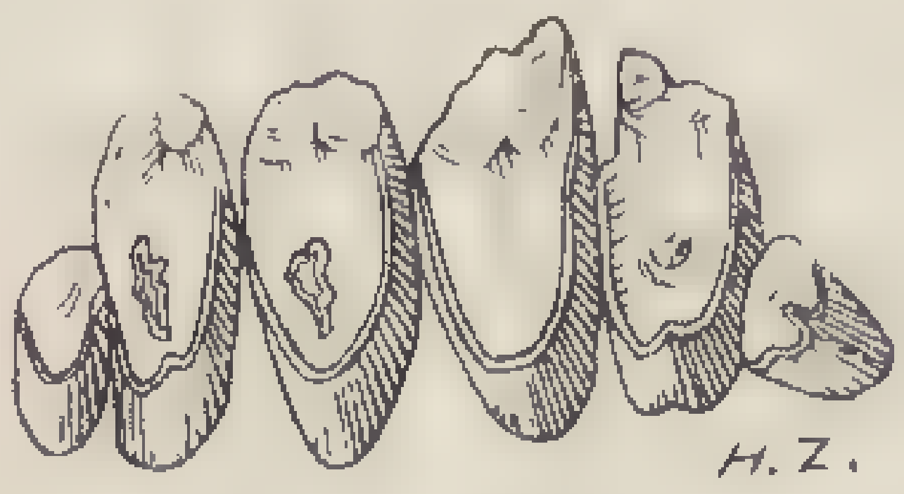

FIG. 5. *Hyolagus primitivus.* Type. Superior view of P^2–M^3. Twice natural size. Drawn by Helen Ziska.

The palate is broad and the palatine fissure is developed about as in *Lepus* and occupies the same position. The internal nares are broadly open and extend forward to opposite the center of M^1. The skull is deep, the orbit is relatively large and the postorbital process of the frontal is developed about as in *Archaeolagus.*

As shown by Dr. Dice (1917, p. 181) the genus *Hypolagus* is distinctive, not only in the crenulated re-entrant angles of the superior molar teeth, but also in the presence of two exterior re-entrant angles in P_3. Unfortunately the lower jaw of *H. primitivus* is not known. The occurrence, however, of a shallow groove extending from the antero-external corner of P^2 to the center of the crown probably indicates the emphasis of the anterior fold on P_3 which would be brought about by the development of two external re-entrant angles on that tooth. *H. primitivus* affords the only information we have of the upper dentition of an early Miocene member of this genus. In so far as is known the upper dentition, particularly in the primitive state of P^3, in the less crenulated internal re-entrant angles and in the absence of cement, is more primitive than any of the later species. *H. primitivus* forms an excellent stage which, for the time being, may be considered directly ancestral to the later members.

Too little is known about the later Oligocene and early Miocene lagomorphs to say with certainty what was the ancestry of *Hypolagus*. Dr. Dice has suggested (1917, p. 182), that *Archaeolagus* might have been the progenitor of *Hypolagus*. Occasionally the upper teeth of that genus display a slight folding in the enamel of the internal re-entrant angle. It should be called to mind, however, that this feature is also present in *Palaeolagus agapetillus* and it is probable that *Hypolagus* may have come directly from that genus.

Measurements

	mm.
Distance from P^2–M^3 on alveoli	14.7
Distance from P^2–P^4 on alveoli	7.7
Greatest length of P^3	2.4
Greatest width of P^3	4.6
Greatest length of P^4	2.4
Greatest width of P^4	5.2
Greatest length of M^1	2.5
Greatest width of M^1	5.0
Greatest length of M^3	1.3
Greatest width of M^3	2.2
Vertical diameter of orbit	14.8

ARCHAEOLAGUS ENNISIANUS (Cope)

Material. A left maxilla with P^2–M^2, M. C. Z. No. 2,888. Collected by Erich M. Schlaikjer, 1930.

Horizon and locality. Lower Miocene. Lower Harrison formation, approximately 200 feet above the Brule-lower Harrison contact. N.W.¼. Sec. 36. T. 20N. R. 62W. Goshen County, Wyoming.

Discussion. This specimen seems near to *A. ennisianus* in size, in the spacing of the teeth and in the shallow invasion of the internal re-entrant angles into the teeth crowns. There are also faint remnants of exterior enamel crescents which seem to connect with the outer margins of the teeth. In so far as is known, this is an *Archaeolagus* character. It differs from the above species, however, in having a weaker anterior groove on P^2 and, as is indicated by the alveolus, in a proportionately larger M^3. This specimen was collected from beds which are probably stratigraphically higher than the John Day in which *A. ennisianus* occurs, and when more completely known, may represent a distinct species.

Suborder SIMPLICIDENTATA

Family CASTORIDAE

PALAEOCASTOR sp.

Two excellent skulls, M. C. Z. Nos. 2,927 and 2,886, and a partial skull and skeleton, M.C.Z. No. 2,916, referable to the genus *Palaeocastor*, were collected from the lower Harrison beds in the Goshen Hole Area. A left mandible, M. C. Z. No. 2865, was collected from the *Parahippus* level of the lower part of the upper Harrison. None of these specimens are assignable to any of the described species of this genus. Dr. R. A. Stirton has in press a monograph on the beavers. This extensive piece of research includes a revision of the group and descriptions of new forms. To avoid possible synonymy and additional complication of the literature it is deemed advisable to postpone an account of the material at hand.

Family SCIURIDAE

SCIURUS sp.

A fine skull, jaws and greater portion of the skeleton, M. C. Z. No. 2,928, which is probably referable to the genus *Sciurus* was found in the lower Harrison beds on Bear Creek Mountain. A study and description of this specimen will appear later when it has been prepared in the laboratory.

Order CARNIVORA

Suborder FISSIPEDIA

Family CANIDAE

CYNODICTIS GREGARIUS (Cope)

Material. Right lower jaw with C–M_3, M. C. Z. No. 2,884a, and the left facial portion of a skull with I^3–P^2 and three upper first molars, M. C. Z. Nos. 2,884b-f. Collected by Erich M. Schlaikjer, 1932.

Horizon and locality. Middle Oligocene. Brule formation, upper part of the middle oreodont zone. Harvard Fossil Reserve. Goshen County, Wyoming.

Discussion. The known stratigraphic range of this species is throughout the oreodont zone or lower and middle Brule of the White River beds. In South Dakota and Nebraska it seems to occur most abundantly in the middle level of this zone. Its occurrence in the Harvard quarry is of significance, therefore, since it aids, as well as a number of other distinctive forms, in correlating this deposit with the middle oreodont level of the Big Badlands.

Dr. Thorpe has stated (1924, pp. 425–427) that *C. gregarius* (Cope) is identical with *C. angustidens* (Marsh) and since the latter was described at an earlier date it has precedence over *C. gregarius*. After a comparison of Professor Cope's type with Dr. Thorpe's figure of *C. angustidens*, a jaw fragment with three premolars, it seems that the latter is distinct in at least two important characters. First, the posterior basal cusp on P_4 is much better developed and second, the ramus, especially anterior to P_4, is deeper and less tapering. It is, therefore, considered advisable, for the present at least, to regard *C. gregarius* as valid.

NOTHOCYON LEPTODUS[1] sp. nov.

Type. A fragmentary left lower jaw with P_4–M_2 and the alveoli of M_3 and C–P_3, M. C. Z. No. 2,878. Collected by Erich M. Schlaikjer, 1933.

Horizon and locality. Lower Miocene. Lower Harrison formation, approximately 15 feet above the Brule-lower Harrison contact. N.W.¼. Sec. 7. T. 25N. R. 63W. Goshen County, Wyoming.

Specific characters. About the size of *N. annectens* from the lower Harrison of Nebraska. M_1 relatively narrow and the endoconid crest-like. M_2 relatively long. P_4 narrow and with the posterior cusp not exterior to the main cusp. Mandible proportionately deep under M_1 (See Figure 6).

Discussion. Of the specimens assigned to *Nothocyon*, *N. leptodus* seems closer to the *N. annectens-latidens-lemur* group of smaller forms rather than to the larger *N. geismarianus-gregorii-vulvinus* species. Its closest affinities are to *N. latidens* (Cope) of the upper Oligocene, John Day beds and *N. annectens* Peterson of the lower Harrison. In size and in the general tooth proportions it is closer to the latter while in the less crowded condition of the premolars and in the relatively deep mandible it appears to be more closely related to *N. latidens*. From the early "typical" *Nothocyon, N. leptodus,* in so far as is known, has digressed mainly in the relatively large size and narrow proportions of the inferior premolar-molar teeth. In these characters, *N. annectens* is even more primitive. These two species are small primitive forms that existed on into early Miocene. They represent a phylogenetic line less progressive than that of *N. gregorii* and *N. vulvinus,* the larger and more specialized members of the genus.

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[1] From the Greek, λεπτος, narrow; *οδους*, tooth; in allusion to the narrow M_1.

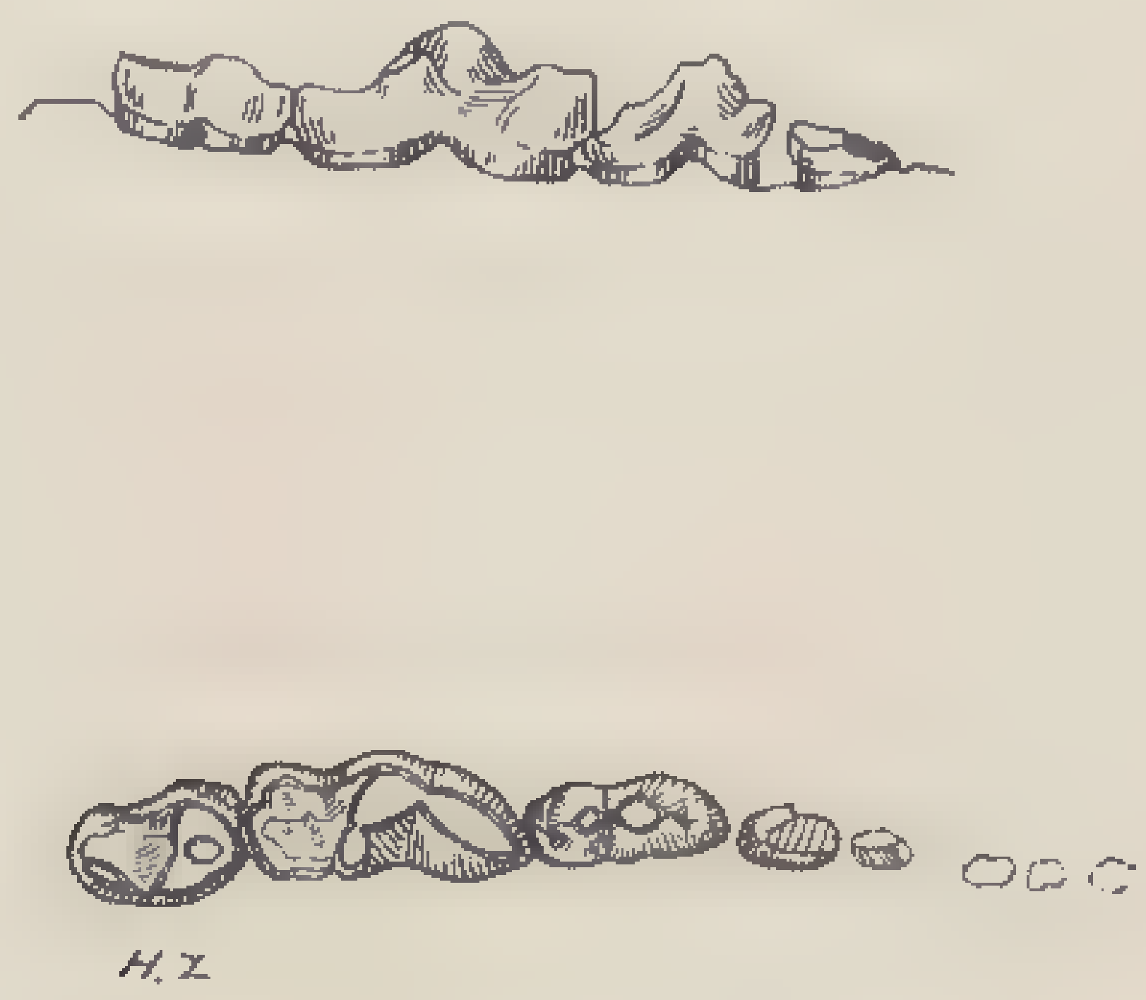

FIG. 6. *Nothocyon leptodus.* Type. Lateral and superior views of the left mandible. Natural size. Drawn by Helen Ziska.

From Dr. Matthew's 1924 phylogeny of the Canidae (p. 122) one would infer that he considered all of the American representatives of *Cynodictis,* at least *C. temnodon* and *C. gregarius,* as belonging to *Nothocyon.* In other parts of the same paper (pp. 119, 120, 128, etc.), however, he repeatedly refers to them as members of "*Pseudocynodictis,*"— a generic name proposed by Schlosser for the American representatives. In his later paper "The phylogeny of the dogs" (1930), Dr. Matthew seemingly regards *Cynodictis* as including the American species. Whether or not these species should be included in a genus distinct from *Cynodictis* is of no particular concern in the present consideration. It is of importance, however, that they be regarded as generically distinct from *Nothocyon,* the species of which in almost all of their dental and cranial characters are decidedly less viverrine and more dog-like.

Measurements

	mm.
Length of P_2–M_3 on alveoli	34.3
Length of P_4	5.9
Width of P_4	2.5
Length of M_1	9.3
Width of M_1	3.9
Length of M_2	5.3
Width of M_2	3.5
Depth of mandible under center of M_1	11.4

MESOCYON HORTULIROSAE sp. nov.

Type. A complete and excellent preserved skull and jaws, M. C. Z. No. 2,102. Collected by Mrs. C. W. Culley[1], 1928.

Horizon and locality. Lower Miocene. Lower Harrison formation. N.W.¼. Sec. 36. T. 20N. R. 62W. Goshen County, Wyoming.

Paratype. An incomplete pair of lower jaws with the premolar and molar teeth, M. C. Z. No. 2,882. Collected by Erich M. Schlaikjer, 1933.

Horizon and locality. Lower Miocene. Lower Harrison formation, approximately 120 feet above the Brule-lower Miocene contact. S.E.¼. Sec. 22. T. 20N. R. 60W. Goshen County, Wyoming.

Specific characters. In size, about the same as *M. josephi* and *M. brachyops*. Face elongate, low and narrow. P^4 with relatively long heel. P^2 and P^3 proportionately small and the latter crowded close to P^4. M^2 proportionately wide. Palate narrow. Basicranial area relatively short. (See Figures 7–10, and Plate 11).

Description and discussion. The upper tooth series is relatively long. I^3 is proportionately small. The canines are not preserved although the roots and alveoli indicate that they were proportionately smaller than those of *M. coryphaeus* (Cope) and proportionately larger than those of *M. josephi* (Cope). There is a short space between the C and P^1, between P^1 and P^2 and between the latter and P^3 which is closely set against P^4. P^3, as in *M. josephi*, does not possess a posterior cusp. The protocone (deuterocone) of P^4 is more reduced and, mainly as a result of this, the shear of that tooth is in a more antero-posterior

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[1] A small block of sandstone containing the specimen was used for some time as a door stop at the home of Mrs. Culley near Huntley, Wyoming. Later, it acted as one of the ornaments in her rose garden. It was presented to the author in 1931.

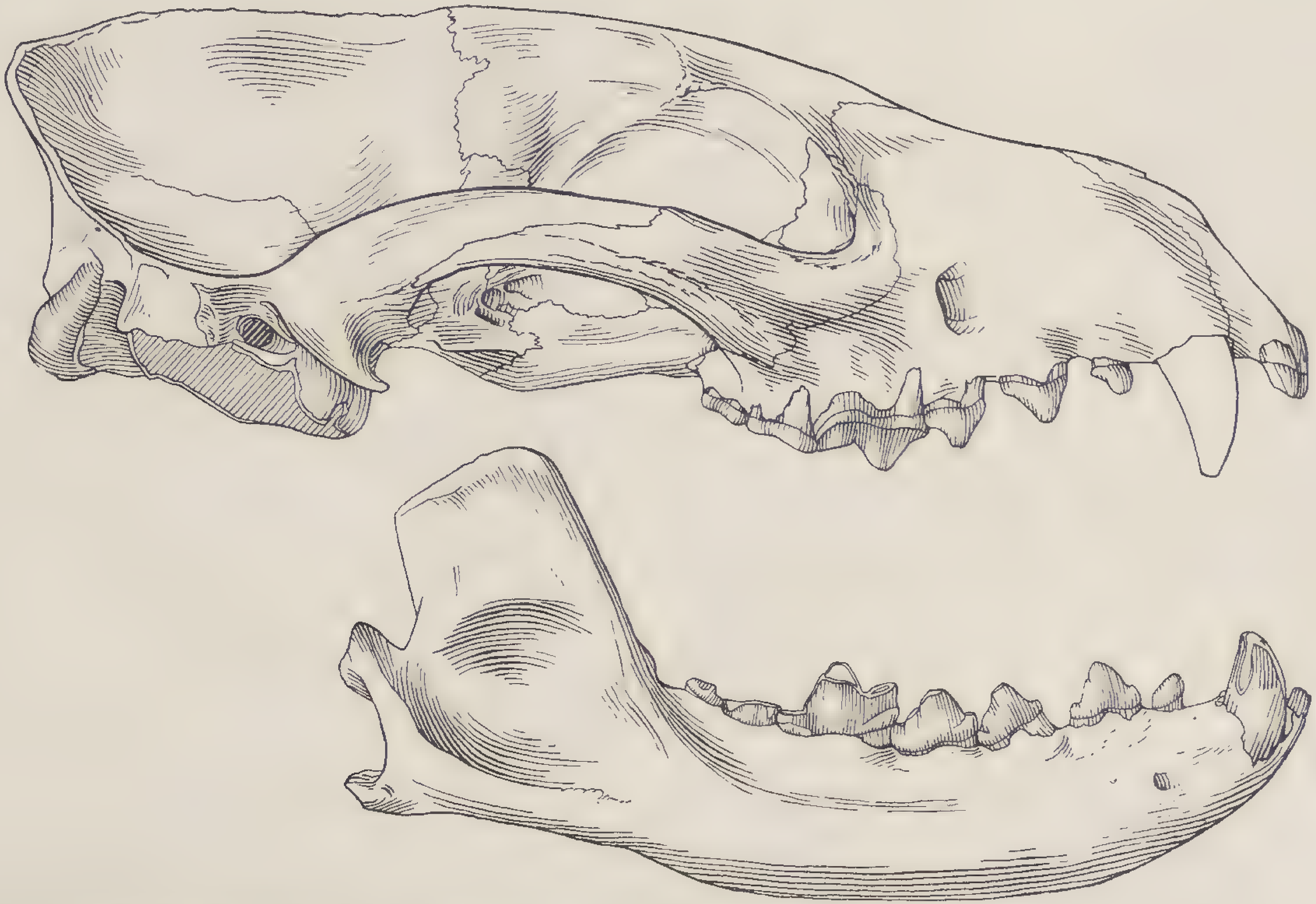

Fig. 7. *Mesocyon hortulirosae*. Type. Lateral view of the skull and jaws. Natural size. Drawn by Louise W. Germann.

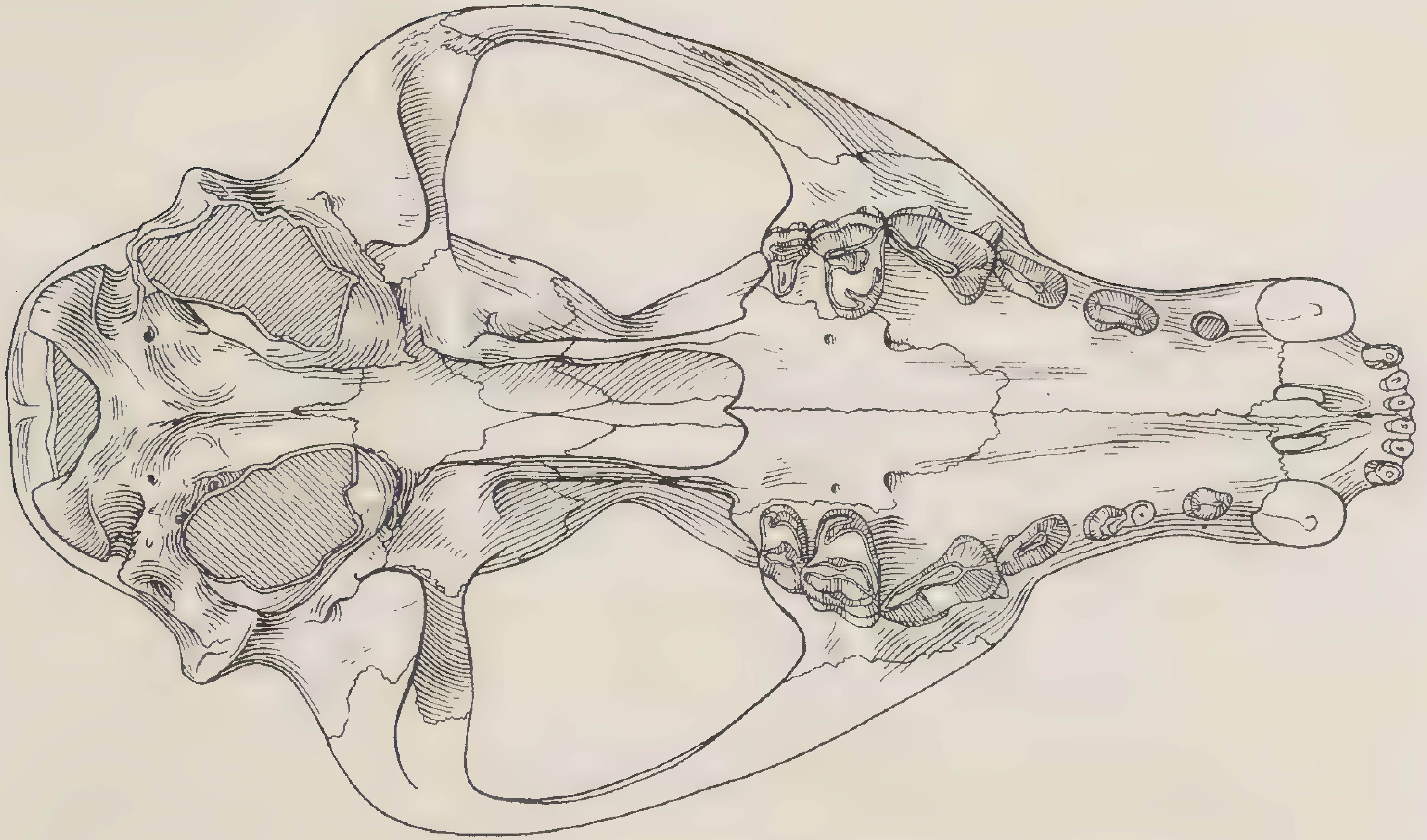

FIG. 8. *Mesocyon hortulirosae.* Type. Palatal view of the skull. Natural size. Drawn by Louise W. Germann.

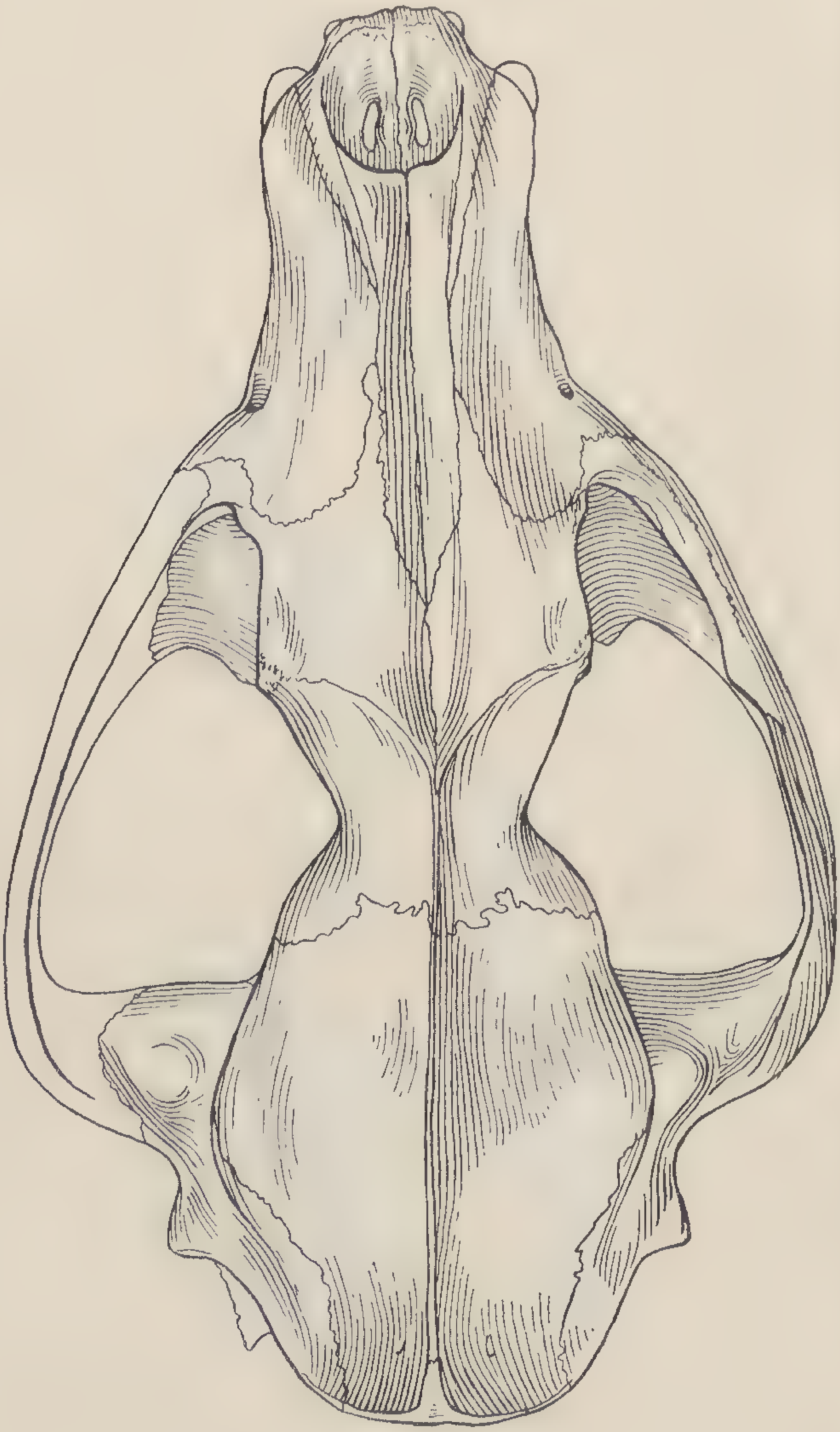

Fig. 9. *Mesocyon hortulirosae.* Type. Dorsal view of the skull. Natural size. Drawn by Louise W. Germann.

position than in any of the other species. Also, M^1 is relatively wide and the hypocone cusp does not extend as far anteriorly. M^2 is large,—a *Cynodesmus* feature. As a matter of fact, in nearly all of its dental characters *M. hortulirosae* is very close to that genus. Of the lower teeth, P_2 and P_3 are relatively small. The left P_4 has an accessory postero-internal cusp which is lacking in the right. The metaconid of M_1 is very well developed and the protoconid and metaconid of M_2 are pronounced and quite separated.

The basioccipital is broad and displays a heavy median ridge on either side of which is a shallow depression immediately in front of the foramen hypoglossi. The distal end of the paroccipital process is lost but the base indicates that it was short, heavy and firmly braced against the bulla. The bulla is developed about as in *Canis* except that the endotympanic is proportionately somewhat larger. The external auditory meatus is annuloid and on the anterior margin is a slight projection in front of which is the temporal canal. The occipital condyles are narrow, are widely separated above and below and occupy an oblique supra-anterior ventro-inferior position. The supraoccipital is high and presents a faint median ridge. The interparietal is small, and the lambdoid and sagittal crests are quite prominent. The cranium is proportionately very expanded posteriorly and the parietal and squamosal bones are about as inclusive as in *Canis*. The postorbital constriction is very marked and the frontal crest is weakly developed and extends out to the suppressed postorbital process. The lacrimal is fairly large and its external margin is restricted to the anterior border of the orbit. The lacrimal foramen is large and round. The malar is extensive and posteriorly it presents a small postorbital process. The orbit is rather small and is oval in outline. The nasals are narrow throughout most of their length and widen anteriorly. Posteriorly they are wedged between the two long anteriorly projecting processes of the frontals. The face is somewhat abruptly constricted above P^2 and widens again across the canines. The infraorbital foramen is large, circular and is located immediately above the posterior part of P^3. The dorsal posterior projection of the premaxillary is considerably separated from the frontal. A minute foramen incisivum is present just anterior to the fairly large oblong palatine fenestrae. The palate is relatively narrow and flat and the palatine extends forward to opposite the middle of P^3. The palatine grooves are very distinct and the palatine foramina are small, round and are situated opposite Ms^1. The internal narial opening is extended only slightly behind the last molar. The dorsal wing of the palatine appears more elongated than in *Canis* because it is not so ventrally extended. The posterior palatine and the sphenopalatine foramina are close together and the latter is slightly larger. The alar canal is large and is separated from the foramen orbitale which is a trifle larger. Slightly above and in front of the latter is the optic foramen which is much smaller. There is no orbitosphenoid ridge anterior to these foramina. The distal ends of the pterygoids are broken away. Dorsally the pterygoids barely unite over the suture between the basisphenoid and vomer. The vomer is narrow and has a low median ridge.

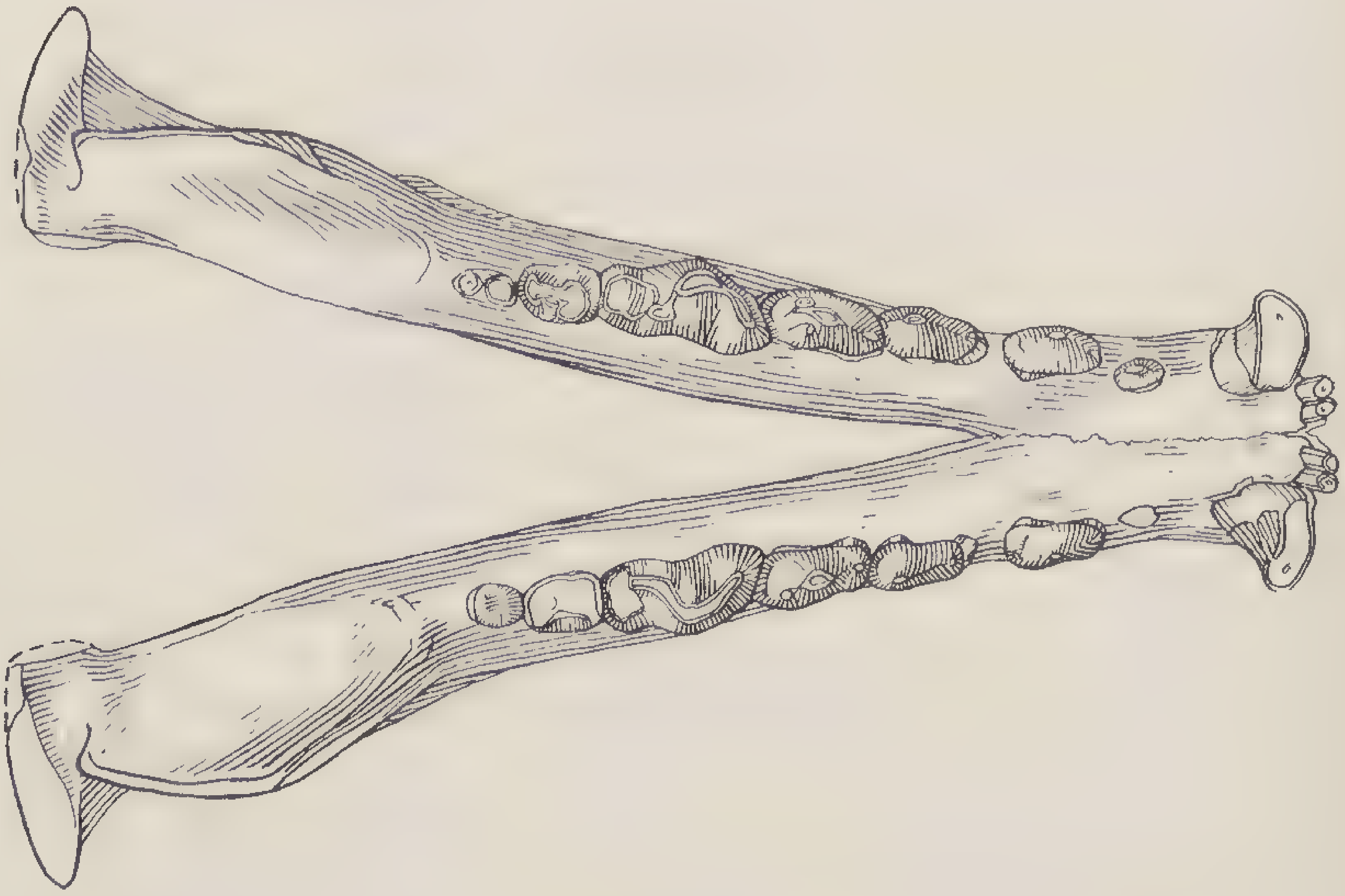

FIG. 10. *Mesocyon hortulirosae* sp. nov. Superior view of the lower jaws. Natural size. Drawn by Louise W. Germann.

The mandible is relatively long and slender. The condyle is narrow and is extended transversely. The coronoid is high, compressed and of large antero-posterior dimension. There is a large hook-like process protruding posteriorly and internally at the angle. Immediately anterior to this is the fairly small foramen mandibulare. The mandibular notch is widely open.

Compared with the other species of *Mesocyon, M. hortulirosae* is nearest to *M. josephi* (Cope) of the upper John Day. From this species it is different, however, in the following characters:

1. A relatively smaller I^3.
2. P^1 closer to the canine.
3. P^3 more closely crowded against P^4.
4. Protocone (deuterocone) more reduced.
5. M^1 more antero-posteriorly constricted internally.
6. M^2 proportionately much larger.
7. Posterior portion of P^4 more elongated.
8. Facial region more shallow.

Considering its general assemblage of characters, *M. josephi* is structurally, as well as stratigraphically, an ideal ancestor for *M. hortulirosae*. One other species, *M. robustus* Matthew, has been described from the Great Plains region[1]. This species was based on a pair of lower jaws collected from the lower Harrison (lower Rosebud) of South Dakota. In one character, the incipient development of the metaconid on M_2, *M. robustus* is distinct from all other species and is close to *Temnocyon*. In addition, *M. hortulirosae* is different from *M. robustus* in its smaller size, in the relatively smaller P_2–M_1, and in the relatively larger M_2 and M_3. Out on the Great Plains in the early Miocene, *M. robustus* and *M. hortulirosae* respectively occupied the same habitat as did *M. coryphaeus* and *M. josephi* in the late Oligocene, John Day times.

After a study of *M. hortulirosae*, as well as the other species of *Mesocyon* I am unable to find a single important character in this genus which is not transitional between *Daphaenus* of the Oligocene and *Cynodesmus* of the Miocene.

Measurements

	mm.
Basal length of skull	130.8
Condylo-basal length	137.2
Greatest zygomatic breadth on squamosals	80.5
Greatest breadth across squamosals on cranium	43.5
Breadth of upper rim of postglenoid notch	48.5
Breadth of postorbital constriction	18.0
Distance from anterior rim of orbit to pmx. (anterior of I alveoli)	48.5
Distance from anterior rim of orbit to supraoccipital crest	94.5

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[1] I regard *M. drummondanus* Douglass from the upper Oligocene? of Montana as belonging to *Daphaenus* rather than to *Mesocyon* to which genus it was tentatively referred by Mr. Douglass.

Distance from mandibular condyle to pmx.	102.0
Greatest width of condyles	29.5
Distance from ventral portion of occipital condyles to supraoccipital crest	37.0
Distance from anterior of I^1 alveolus to internal nares	66.0
Breadth of muzzle at openings of infraorbital foramina	28.0
Width of premaxillaries on I^3 alveoli (external)	13.5
Distance between canines	14.5
Breadth across Ps^1 on alveoli	20.7
Breadth across Ms^1 on anterior alveoli	43.0
I^3 to P^4 on alveoli	54.5
I^3 to M^2 on alveoli	64.5
P^1 to P^4 on alveoli	37.5
M^1 to M^2 on alveoli	13.5
Length of P^4	12.0
Greatest width of P^4	7.8
Length of M^1	9.0
Greatest width of M^1	11.5
Length of M^2	4.5
Greatest width of M^2	9.0

Measurements of referred skeleton

Width of distal end of humerus	38.5
Length of femur, great trochanter to condyle	139.0
Width across condyles	32.5
Smallest transverse diameter of femur shaft	11.0
Greatest length of tibia	124.5
Width of proximal end of tibia	31.0
Width of distal end of tibia	22.5
Greatest length of fibula	111.5
Greatest length of calcaneum	40.0
Height of cuboid	15.0
Length of metatarsal 1	27.0
Length of metatarsal 2	35.0
Length of metatarsal 3	42.0
Length of metatarsal 4	44.0
Length of metatarsal 5	39.5

Order PERISSODACTYLA

Superfamily EQUOIDEA

Family EQUIDAE

Pediohippus antiquus[1] gen. et sp. nov.

Type. A left maxilla with P^2–M^3, M. C. Z. No. 2,790. Collected by Erich M. Schlaikjer, 1930.

Paratype. A nearly complete skull with complete cheek dentition, M. C. Z. No. 2942. The following specimens are also referred to this species: a right maxilla with P^2-M^3, M. C. Z. No. 2,789; a palate with complete cheek teeth, M. C. Z. No. 2,791; a right maxilla with P^1–M^3, M. C. Z. No. 2,792; a left maxilla with P^4–M^3, M. C. Z. No. 2,793; and, a large number of jaws and isolated teeth.

Horizon and locality. Middle Oligocene, Brule formation, upper part of the middle oreodont zone. Harvard Fossil Reserve. Goshen County, Wyoming.

Generic characters. Metaloph with crochet but not united to ectoloph except in M^3 of the later forms. Upper incisors deeply cupped and cingule of lower incisors larger than in *Mesohippus*. A metatarsal III-cuboid facet.

Specific characters. Somewhat larger than *Mesohippus barbouri*. Teeth as hypsodont as in *Parahippus pristinus*. Crochet developed on M^1–M^3. P^4 and M^1 subequal in size. Styles on teeth rather weakly developed. (See Plate 12).

Discussion. As stated previously horses are the most abundant of the fossils which occur in the Harvard quarry. The occurrence of so many individuals whose remains accumulated, as is designated by stratigraphic evidence, in a comparatively short time is particularly welcome and of striking significance. For the first time it is now possible to say with reasonable certainty how much variation is to be expected, in the dentitions at least, in the earlier of the Oligocene horses. Likewise, it should be called to mind that this period is probably the most critical in the evolution of the horse, for the direct ancestral forms of at least five important late Oligocene and early Miocene genera were becoming established. Perhaps never before and not since that time has there been such an adaptive radiation of the Equidae.

A study of the dentitions and skeletal remains of over fifty specimens together with a survey of the other Oligocene and early Miocene species reveals the following outstanding facts concerning evolutionary changes in the direct line of ancestry of the horse from *Pediohippus antiquus* of the middle Oligocene to *Parahippus pristinus* of the lower Rosebud:

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[1] From the Greek, πεδιον plains; ιππος horse.

1. The cheek teeth do not become more hypsodont.
2. There is only a slight increase in tooth dimensions.
3. The proportionate lengthening of the premolars is remarkably small.
4. The incisor teeth do not become more deeply cupped.
5. There is practically no additional strengthening of the metatarsal III — cuboid facet.
6. There was a small amount of increase of size and slight changes in proportions,— especially in the limbs.
7. A union of the metalophs with the ectolophs.
8. A development of a crochet on P^2–M^3.

All of the above changes except the latter were also accomplished in such collateral forms as *Anchitherium* (including *Kalobatippus* perhaps), *Archaeohippus* and *Hypohippus,* which survived to late Miocene or early Pliocene times. It was only in *Pediohippus,* however, that the crochet was developed,— primitively on the last molar, later on all three molars, and eventually on all of the cheek teeth. (See Plate 12). In the *Parahippus pristinus* stage, in addition to the development of a crochet on the cheek teeth, the metalophs unite with the ectolophs. From this stage onward, concomitant with an increase of hypsodonty, the crochet increases, forms isolated valleys in which cement is deposited, and later on unites with the protoconule coincident with which the protocone begins to become isolated from the protoloph,— a *Merychippus* stage in which the essential tooth pattern of *Equus* is established. In *Hypohippus* of the early Miocene the metaloph has united with the ectoloph but from then on progression of tooth evolution is arrested and increase of size is the only dominant change. *Hypohippus matthewi* of the lower Pliocene, for example, has teeth which are gigantic in size. Each superior molar has a grinding surface area of approximately three square inches, yet structurally the tooth amounts to nothing more than that of an inflated *Miohippus* from the upper Oligocene. These same conditions prevail in *Anchitherium* although with size increase more inhibited in this genus,— a feature even more pronounced in the rather rare little *Archaeohippus.* The crochet, so characteristic of *Pediohippus, Parahippus* and all of the later stages in the direct line of *Equus* ancestry, is never present on the teeth of these genera. The development of the crochet, therefore, is the most important single character in dental change during the evolution of the direct progenitors of the horse, particularly in the formative period from Oligocene to Miocene times.

	M.C.Z. 2789	Type M.C.Z. 2790	M.C.Z. 2791	M.C.Z. 2792	M.C.Z. 2942	M.C.Z. 2793	Variation
P^2–M^3	76.0	76.0	73.7	76.6	80.0	?	6.3
P^2–P^4	38.2	38.8	36.7	36.6	39.2	?	2.6
M^1–M^3	40.9	40.7	39.9	40.9	42.2	36.7	5.5
P^2 length	12.8	13.2	12.1	12.6	13.6	?	1.5
P^2 breadth	12.7	12.9	11.7	13.1	13.7	?	2.0
P^3 length	?	14.0	13.0	13.1	13.4	?	1.0
P^3 breadth	15.6	15.5	13.5	15.8	15.4	?	2.3
P^4 length	14.5	15.1	13.3	13.3	14.9	13.6	1.8
P^4 breadth	17.1	16.1	15.3	15.7	17.5	15.0	2.1
M^1 length	14.5	15.0	14.5	14.2	14.7	13.3	1.7
M^1 breadth	16.5	17.6	15.6	15.8	17.7	15.6	2.1
M^2 length	14.7	15.4	13.7	14.2	15.2	13.7	1.7
M^2 breadth	17.4	17.7	16.1	17.0	17.1	15.9	1.5
M^3 length	14.4	14.9	13.9	13.3	13.6	13.0	1.9
M^3 breadth	17.4	16.6	15.6	15.4	15.2	15.4	2.2

TABLE 1. Measurements of six specimens of *Pediohippus antiquus* showing variation in dentition.

The crochet in *Pediohippus antiquus* shows a certain amount of variation and some forms correspond very closely to *Mesohippus bar-*

bouri which also occurs so abundantly in the Harvard Quarry. In a large assemblage of teeth *M. barbouri* seems transitional to *P. antiquus*. One specimen of the latter, M. C. Z. No. 2,791, is almost indistinguishable from *M. barbouri* except for the development of an incipient crochet on the last molar. Then too, there is an occasional specimen with a crochet on M^2 and M^3 but none on M^1. This variability in the number of teeth with a crochet is not surprising, for the existing in the same oecologic niche of hundreds of individuals, representing at least three species, is bound to result in considerable hybridization, which would certainly account for this variation. In Table 1, measurements are listed for six specimens of *P. antiquus*. The figures given show a fair amount of variation which is due mainly to a discrepancy in size rather than to a difference in proportions. Likewise structural differences in dentition are peculiarly few. The hypostyle, for example, is remarkably constant in its form and position. It is comprised of an enlargement of the central area of the posterior cingulum which is connected with the postero-internal face of the hypocone by a small conule. Occasionally M^3 shows a digression from this usual pattern in the absence of the conule and is, therefore, more primitive in that respect.

In the genus *Pediohippus* several previously described species of *Mesohippus* and *Miohippus* may be included. They are as follows:

1. *Mesohippus portentus.* This species was described by Mr. Douglass in 1908 (pp. 268–269) as from the "Lower White River ('Titanotherium') beds, pipestone Creek, near Whitehall, Montana." The type is a second right superior molar on the metaloph of which is a well developed crochet. As suggested by Professor Osborn (1918, p. 45), the tall crown, the well developed crochet and the close approximation of the metaloph certainly indicate a form too advanced for the lower Oligocene. This form is very close to "*Miohippus*" *gidleyi* (Osborn) of the upper Oligocene and when more completely known may be found to represent the same species.
2. *Mesohippus trigonostylus.* Professor Osborn described this species in 1918 (pp. 47–48). Recent excavation has revealed a distinct crochet on M^3. This, of course, was not mentioned in Professor Osborn's description; neither was it shown on the original figure. Stratigraphically this specimen occurs in the *Metamynodon* sandstone which is slightly older than the beds of the Harvard quarry.
3. *Miohippus brachystylus* (Osborn). This species was found in the *Leptauchenia* beds of the upper Oligocene. A crochet is present on P^3–M^3. It forms an excellent intermediate stage between *Pediohippus antiquus* and *Parahippus pristinus* (see Plate 12).

4. *Miohippus intermedius* (Osborn and Wortman). This is a species from the upper Oligocene of South Dakota. It cannot be regarded as directly ancestral to *Parahippus pristinus*, however, because: a. The superior incisor teeth are not as advanced as in *Mesohippus barbouri* and *Pediohippus antiquus* of the middle Oligocene. b. The teeth are considerably larger and the premolars are proportionately too broad. c. A crochet is developed only on M^3. (It is of interest to note that M^3 not only has a crochet but the metaloph is united with the ectoloph. This tooth which is frequently the most primitive of the series is the most advanced in *Pediohippus*, for in this genus it is the first tooth to possess a crochet and the first to have the metaloph united with the ectoloph).
5. *Miohippus gidleyi* (Osborn). This species is somewhat larger than *M. intermedius*. The crochet is present on P^3–M^3. It has progressed over *M. brachystylus* only in size,— being considerably larger than *Parahippus pristinus* and probably not ancestral to the latter.

In Plate 12 the upper cheek teeth of three *Pediohippus* species,— *P. trigonostylus*, *P. antiquus* and *P. brachystylus*, are shown together with the premolar-molar series of *Parahippus pristinus*. All are types except *Pediohippus trigonostylus*. Another specimen, Amer. Mus. 674, was selected instead of the type only because the stage of wear was more nearly like that of *P. antiquus*. In every respect it is identical with the type, and was collected in the same locality and from the same beds which are slightly older than the deposit at the Harvard quarry. This series of dentitions illustrates the evolutionary changes which took place in the premolar-molar teeth of the direct progenitors of the modern horse during early middle Oligocene to lower Miocene times. The more salient of these changes are the following:

1. The crochet is developed on all of the teeth. It gradually increases in size and becomes more closely approximated to the protoconule.
2. The union of the metalophs with the ectolophs is completely established.
3. There is an extension of the protolophs so that they unite more firmly with the parastyles which become less angulate.
4. There is a proportionate enlargement of the protocone.
5. The crowns of the teeth become more quadrate.
6. P^2–P^4 gradually become longer than M^1-M^3.

As mentioned above, except for the presence of a crochet, it is sometimes difficult to distinguish between *Pediohippus antiquus* and *Mesohippus barbouri*. Even in this character there is every gradation from a well developed crochet on all three molars, to the merest welt on the metaloph of M^3, to the absence of a crochet. This is indeed not surprising. The more complete the palaeontological record, the greater will be the difficulty of distinguishing the more progressive members of an early genus from the primitive members of a later genus. This is particularly true of the horses of which the evolutionary sequence is especially complete. Certainly the presence of a crochet on the metaloph, together with other skeletal differences such as the metatarsal III-cuboid facet, is of greater significance in separating *Pediohippus antiquus* from *Mesohippus barbouri* than is any character seen in *Merychippus gunteri* which separates it from *Parahippus leonensis* or *Merychippus primus* from *Parahippus brevidens*.

MESOHIPPUS BARBOURI Schlaikjer

Material. A rather complete skull, M. C. Z. No. 2,778 (see Plate 13), and a great number of palates, maxilla with P^1–M^3 and lower jaws. Also an abundance of fragmentary skulls, isolated teeth and jaw fragments. Collected by the Museum of Comparative Zoölogy expeditions 1930–1934.

Horizon and locality. Middle Oligocene. Brule formation, upper part of the middle oreodont zone. Harvard Fossil Reserve, Goshen County, Wyoming.

Discussion. Previously this species was known only by a single specimen, the type M. C. Z. No. 17,641, which is an unusually complete skeleton from the upper concretionary layer of the Brule formation in the Big Badlands, South Dakota. The occurrence of this species in such abundance in the Harvard quarry is of significance. Together with the assemblage of other genera and species that are found in this rich deposit, it shows that the geological level of the beds at the quarry can be correlated with the upper concretionary zone in the South Dakota Badlands. The skull figured in Plate 13, as far as the characters are preserved is identical with the type. In spite of the close similarity to *Pediohippus antiquus*, this species is typically smaller, has proportionately narrower premolars, has a more primitive hypostyle and, of course, does not have the metatarsal III-cuboid facet. In addition, the lower teeth are relatively narrower and the symphysis is proportionately shorter and heavier.

By comparative measurements of teeth of ten individuals, given in Table 2, it is shown that this species presents little variability in dentition.

MESOHIPPUS OBLIQUIDENS Osborn

Material. A left maxilla with P^2–M^3, M. C. Z. No. 2,785, and a large number of isolated teeth. Collected by the Museum of Comparative Zoölogy expeditions 1930–1933.

	M.C.Z. 2778	M.C.Z. 2779	M.C.Z. 2780	M.C.Z. 2781	M.C.Z. 2782	M.C.Z. 2783	M.C.Z. 2784	M.C.Z. 2786	M.C.Z. 2787	M.C.Z. 2788	Size Variation
P^2–M^3	71.8	75.4	71.0	73.9	76.0	?	76.0	?	?	?	5.0
P^2–P^4	36.1	37.7	36.8	34.9	37.8	38.0	37.7	?	?	39.8	4.9
M^1–M^3	39.4	39.9	38.1	41.1	40.6	?	41.2	?	?	?	3.1
P^2 length	11.8	13.1	12.0	11.8	12.8	12.8	12.2	?	?	12.7	1.3
P^2 breadth	11.8	12.2	13.1	12.7	12.5	11.3	11.7	?	?	12.5	1.8
P^3 length	13.3	12.9	12.5	13.0	18.9	12.9	13.0	13.0	13.4	14.4	1.9
P^3 breadth	14.1	14.6	15.0	15.1	14.6	14.0	14.0	15.0	15.6	14.5	1.6
P^4 length	13.5	13.3	12.4	13.3	14.4	13.4	13.6	13.4	13.2	14.1	2.0
P^4 breadth	15.2	15.4	?	16.3	15.9	15.3	15.7	16.0	16.5	15.4	1.3
M^1 length	14.3	14.1	?	13.9	15.1	15.4	14.9	14.6	14.6	15.7	1.8
M^1 breadth	15.7	16.3	?	16.7	16.1	15.6	15.3	16.5	16.8	16.7	1.5
M^2 length	14.5	14.3	13.9	14.5	14.6	14.3	14.4	13.9	13.5	14.8	1.3
M^2 breadth	16.2	16.3	17.8	17.8	16.3	16.5	16.3	16.8	16.5	17.5	1.6
M^3 length	13.9	14.1	15.0	15.5	13.7	?	14.5	?	?	?	1.8
M^3 breadth	15.9	16.7	15.0	16.9	15.9	?	15.1	?	?	?	1.9

TABLE 2. Measurements (in millimeters) of ten specimens of *Mesohippus barbouri* showing variation in dentition.

Horizon and locality. Middle Oligocene. Brule formation, upper part of the middle oreodont zone. Harvard Fossil Reserve. Goshen County, Wyoming.

Discussion. This species is based on a fragmentary skull and jaws of an immature individual in the American Museum collection. It was collected from the same geological level as *M. barbouri* in the South Dakota Badlands and is only occasionally found in the Harvard quarry. The teeth of this species are approximately fifteen percent larger than those of *M. barbouri.* The molars are more hypsodont and each tooth is more rhomboidal in outline.

MIOHIPPUS SP.

Material. A pair of lower jaws, M. C. Z. No. 2,946 of a very young individual. Collected by Erich M. Schlaikjer, 1933.

Horizon and locality. Lower Miocene. Lower Harrison formation, approximately 100 feet above the Brule-lower Harrison contact. S.E.¼. Sec. 3. T. 20N. R. 60W. Goshen County, Wyoming.

Discussion. The incisors and canines were preserved and resemble very much the permanent teeth of *Mesohippus.* All of the deciduous premolars were lost but a partially erupted M_1 indicates an animal somewhat smaller than *Pediohippus intermedius.* The incompleteness of this specimen prevents specific determination and it is tentatively assigned to the genus *Miohippus.*

PARAHIPPUS ?PRISTINUS Osborn

Material. A left maxilla with DP^{2}-^{4}, M. C. Z. No. 2,867 (see Plate 41), and a right lower jaw with P^3–M^3 of an extremely old individual. Collected by Erich M. Schlaikjer, 1933.

Horizon and locality. Lower Miocene. Lower Harrison formation, approximately 200 feet above the Brule-lower Harrison contact. S.E.¼. Sec. 22. T. 20N. R. 60W. Goshen County, Wyoming.

Discussion. The specimen with DP^{2}-^{4} compares very closely with one in the American Museum, No. 12,915, from the lower Rosebud formation of South Dakota, which is undoubtedly referable to *P. pristinus.* The teeth are somewhat narrower, however, and there is no crochet on DP^3. More complete material is necessary for accurate identification.

Specimen M. C. Z. No. 2,867b is the jaw of an extremely old individual. The crown of M^1 is so completely worn that the roots of that tooth are no longer joined together. Around the roots of several teeth and down in the jaw there is evidence of pathological abnormality. In life this must have been a region of acute infection, a condition not uncommon in very old horses today. Although the dental characters are destroyed by wear, the specimen is of about the same size and proportions as *P. pristinus.*

PARAHIPPUS WYOMINGENSIS[1] sp. nov.

Type. An unusually complete skeleton, M. C. Z. No. 6,390. Collected by Erich M. Schlaikjer, 1933.

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[1] The writer has in press a rather extensive paper on, "A study of *Parahippus wyomingensis* and a discussion of the phylogeny of the genus."

Horizon and locality. Lower Miocene. Lowermost upper Harrison formation, approximately 500 feet above the Brule-lower Harrison contact. S.W.¼. Sec. 10. T. 24N. R. 65W. Goshen County, Wyoming.

Specific characters. Skull length somewhat less than that of *P. tyleri*. Skull proportionately narrow. I^2 smaller and I^3 considerably smaller than I^1. Proportionate shortening of molars and development of crochet intermediate between *P. tyleri* and *P. nebrascensis*. Hypostyle weak and mesially placed so that it is close to the posterior of the hypocone. Hypocone connected with metacone by a thin, narrow, straight ridge which gives a straight posterior margin to the tooth. Cheek teeth, especially $P\frac{4}{4}$ and $M\frac{1}{1}$, proportionately broad. Palate very narrow. Lower canines absent. Limbs very long. Lateral digits short. Metatarsal III proportionately short. (See Plates 14, 15 and 16).

	Maximum length of femur	Maximum length of tibia	Length of metatarsal III	Femuro-metatarsal III ratio
P. wyomingensis M.C.Z. No. 6390	320.0	344.5	223.4	.698
P. sp. Amer. Mus. 13807	285.0	303.0	203.5	.714
P. tyleri Amer. Mus. 13769	276.0	286.0	198.0	.717
P. nebrascensis Carn. Mus. 1440	325.0	325.0	?	?

TABLE 3. Comparative limb measurements and the femuro-metatarsal III ratios of four *Parahippus* specimens.

Discussion. Perhaps the most outstanding single feature of *P. wyomingensis* is the extraordinary length of the limbs in proportion to the dimensions of the skull and of the skeleton. The skull is somewhat shorter and is much narrower than that of *P. tyleri* Loomis, one of the smaller skulled forms, yet the limbs are longer than in any recorded *Parahippus*. In Table 3 comparative measurements of the femur, tibia and metatarsal III are given for the available specimens on which accurate measurements could be had. The nearest approach to *P. wyomingensis* in limb dimensions is *P. nebrascensis* Peterson. The femora of these species are of approximately the same length yet the tibia of *P. wyomingensis* is much longer. The length of metatarsal III in the type of *P. nebrascensis* is not known. Excellently preserved hind limbs and other skeletal parts of a specimen, No. 13,807, in the American Museum collection from the same geological level is undoubtedly referable to this species. Both the metatarsal III and the femur of this specimen are considerably shorter than those of *P. wyomingensis*. While this species possesses limbs which are longer than in any other known *Parahippus*, its femuro-metatarsal ratio is lower than in the other species (see Table 3). It is obvious, therefore, that during this development of longer limbs the enhanced growth of the proximal elements was proportionately greater than that of the metatarsals.

In every essential character of the cheek teeth as well as in other dental and skull characters, *P. wyomingensis* forms an admirable intermediate stage between *P. tyleri* and *P. nebrascensis*. *P. australis* (Leidy) is known only from the second right upper premolar. The position and isolation of the internal cusps (protocone and hypocone) indicate an evolutionary stage about the same as that of *P. nebrascensis*, although a smaller form, and with the evidence at hand there is nothing to rule *P. wyomingensis* out of its direct ancestry.

Parahippus tyleri-wyomingensis-australis-nebrascensis represent a primitive group of large, brachiodont forms, the later members of which became longer limbed.

Measurements

	mm.
Condylo-basal length	312.7
Zygomatic breadth (just posterior to M^1)	114.7
Greatest breadth across squamosals on malar arches	111.1
Greatest breadth across squamosals on cranium	54.5
Interorbital breadth across frontals	72.3
Distance from anterior rim of orbit to pmx.	171.2
Distance from anterior rim of orbit to supraoccipital crest	173.1
Breadth of muzzle at anterior root of M^1	87.2
Greatest width of condyles	51.5
Width of premaxillaries at posterior of I^3 alveoli	35.7
Cheek teeth on alveoli (P^1 to M^3) external	116.8
Distance from P^2 to P^4 on alveoli (external)	59.0
Distance from M^1 to M^3 on alveoli (external)	52.0
Posterior of I_1 to M_3 on alveoli	128.4

Depth of jaw under anterior of M_1	37.8
Distance from P_1 to P_4	55.7
Distance from M_1 to M_3	58.1
Length of scapula (estimated)	230.0
Length of humerus, head to posterior trochlea	198.8
Greatest length of the femur	320.0
Length of femur from head to internal trochlear ridge	291.6
Length of tibia from medial condyle to internal malleolus	344.5
Length of fibula	312.0
Greatest length of calcaneum	91.7
Maximum length of metatarsal III	223.4
Maximum length of metatarsal IV	209.0

Hypohippus avus sp. nov.

Type. Almost complete skull of a colt with complete right deciduous premolars and M^{1-2}, also left P^4–M^2, M. C. Z. No. 2,811. Collected by Erich M. Schlaikjer, 1933.

Horizon and locality. Lower Miocene. Lower Harrison formation, approximately 100 feet above the Brule-lower Harrison contact. S.W.¼. Sec. 16. T. 20N. R. 63W. Goshen County, Wyoming.

Specific characters. A small form. Metaloph firmly united with the ectoloph on P^4 and less strongly on M^{1-2}. Metaloph straight with metaconule very faintly marked. Protoloph not connected with the ectoloph on the crest. Protoconule conical. Anterior cingulum strong, internal cingulum absent. Hypostyle developed as a loop on the inside of the strong posterior cingulum. No hypostyle-hypocone crest. Cheek teeth quadrate in outline, median width of each as great as length on ectoloph. M^1 smaller than P^4 or M^2. Antorbital fossa large and deep. (See Plates 17, 18 and 19).

Discussion. Hypohippus avus is the earliest and smallest known species of this genus. A dental character which is alone sufficient to eliminate it from *Miohippus* is the union of the metaloph with the ectoloph. Compared with the species of that genus, it is somewhat smaller than *M. validus,* of the upper Oligocene, a species which in its large size, its broad relatively hypsodont teeth, its well developed hypostyle-hypocone crest and in a number of other features is already specialized towards the *Anchitherium praestans* line for which it forms an ideal progenitor. *Anchitherium praestans* Cope (*Kalobatippus praestans* Osborn) occurs at approximately the same geological level as *Hypohippus avus. Miohippus brachylophus* (Osborn) from the upper

Oligocene, John Day is somewhat smaller than *H. avus* and is more primitive,— being a "typical" *Miohippus.* Of all the known species of *Miohippus*, it seems nearest the ancestry of the *Hypohippus* line. The more striking dental characters which reveal this affinity are: the form of the hypostyle and its isolation from the hypocone; the quadrate form of the cheek teeth; the reduction of M^1; and, the shelf-like development of the postero- and antero-internal cingula.

Dr. A. S. Romer (1926) has proposed that Professor Osborn's genus *Kalobatippus* be included in the genus *Anchitherium.* In a more recent paper Dr. Simpson (1932, p. 33) has suggested that if this be done, "the more primitive *Hypohippus* group, *H. equinus*, *H. pertinax* and *H. osborni* should be placed there. *H. affinis* (the genotype), *H. nevadensis* and *H. matthewi* are more advanced and distinctive." After a study of the species referred to *Hypohippus* I am unable to find characters in the known material which would permit the separation of the species into two generically distinct groups. In size, reduction of the protoconule and in tooth proportion *H. osborni* seems much nearer to *H. matthewi*, the largest and most specialized of all the known species, than to *Anchitherium.* After a consideration of these facts, and since the discovery of *H. avus* it seems preferable, at least until more complete material is found, to regard *Hypohippus* and *Anchitherium* as distinct genera derived respectively from *Miohippus brachylophus* and *M. validus* of the upper Oligocene. *H. avus* could indeed have been the ancestor of all the later species. Aside from its tooth characters, and even though it is a young individual, it is strikingly similar to *H. osborni* in skull features such as the following:

1. The elongated and expanded cranium.
2. The low facial crests.
3. The proportionately great diameter across the malar portions of the zygomatic arches.
4. The small postorbital bar.
5. The extraordinarily deep and extensive antorbital fossae.

Measurements

	mm.
Condylo-basal length	224.0
Length of P^1–M^2 (including DP^{2-4})	86.0
Length of P^4–M^2	47.0
Greatest length of P^4	17.1
Greatest breadth of P^4	18.3
Greatest length of M^1	17.0
Greatest breadth of M^1	17.8

Greatest length of M^2	17.0
Greatest breadth of M^2	19.0

Superfamily TAPIROIDEA

Family TAPIRIDAE

Genus and species undescribed

During the past field season a fragmentary skull and jaws with complete dentition, and the greater portion of the limbs and other skeletal parts of a tapir were collected from the lower part of the upper Harrison formation in Goshen Hole. This specimen has not as yet been prepared for study. A cursory inspection of the material, however, reveals the fact that this form is a splendid intermediate stage between *Protapirus* of the Oligocene and the recent *Tapirus*. Stratigraphically it is from exactly the same level as *Parahippus wyomingensis* and was found only a short distance from that specimen. A new species of *Oxydactylus* and the jaw of a large *Palaeocastor* were also collected from this same level. The lithology of the beds is a rather fine, unconsolidated gray sandstone which contains a remarkable abundance of plant remains that sometimes constitute over fifty percent of the deposit. This biotic environment would seem to indicate a tropical, densely forested habitat. The occurrence of *Parahippus wyomingensis* in this deposit is of oecological significance. The specializations for forest-living of this species with its relatively long limbs (principally the result of a lengthening of the proximal elements) and brachyodont teeth are in marked contrast to a species such as *Parahippus cognatus* with a hypsodont and more complicated dentition and limbs with the distal elements proportionately more elongated, all of which characters are plains-living and grass-eating specializations.

The discovery of this tapir is of singular importance since not more than three teeth have been previously recorded from the Miocene (excepting perhaps the uppermost portion of the John Day) of North America. The meagre fossil record of tapirs should not be misleading. Probably they have always been forest dwellers (since Oligocene times at least) and the preservation of their remains was perhaps as occasional as was accumulation of sediments in such areas. The family Tapiridae has persisted in the New World during the past sixty million years and there is every reason to believe that during the Miocene the members of this family occurred in numbers commensurate with the living forms.

Superfamily BRONTOTHERIOIDEA

Family BRONTOTHERIIDAE

ALLOPS CF. MARSHI (Osborn)

A right superior P^3 and a right superior M^2, M. C. Z. No. 2948a and b, were collected from about the middle of the Chadron as exposed in Goshen Hole. These teeth were found in the N.W.¼. Sec. 19. T. 23N. R. 61W. In size, in general proportions and in most of the characters they are close to *Allops marshi* and when more completely known this form may be definitely referred to that species. In one important character,— the rather pronounced confluence of the hypocone with the protocone of P^3, this specimen is closer to *Brontops*. Although, this character is somewhat variable in the Menodontine titanotheres.

Fragments of teeth, skulls, jaws and skeletal parts occur abundantly throughout the Chadron beds in Goshen Hole and are very valuable for purposes of correlation. The Colorado Museum expedition in 1931 collected one fragmentary and two fairly complete skulls. These were found in the uppermost level of the Chadron and when studied may prove to be of considerable morphologic interest.

Superfamily RHINOCEROTOIDEA

Family RHINOCEROTIDAE

SUBHYRACODON OCCIDENTALE (Leidy)

Material. An adult skull without the premaxillae, M. C. Z. No. 2,919. (See Plate 41). Collected by Erich M. Schlaikjer, 1932.

Horizon and locality. Middle Oligocene. Brule formation, upper part of the middle oreodont zone. Harvard Fossil Reserve. Goshen County, Wyoming.

Discussion. This specimen agrees closely with Leidy's figures of the type as well as with specimens in the Harvard Museum collection from the middle Oligocene of South Dakota and Nebraska which are also unquestionably assignable to *S. occidentale.* More than fifteen good skulls were collected from one hundred square feet in the south excavation at the Harvard quarry. They occur, therefore, in most unusual abundance. When this material is prepared for study, it may be found that more than one species is represented.

MENOCERAS COOKI (Peterson)

Material. A pair of lower jaws of an old individual, M. C. Z. No. 2,874. Also, a left lower jaw of a young individual with deciduous incisors, DP_4 and M_1, M. C. Z. No. 2,938. Collected by Erich M. Schlaikjer, 1933.

Horizon and locality. Lower Miocene. Lower Harrison formation, approximately 120 feet above the Brule-lower Harrison contact. S.E.¼. Sec. 22. T. 20N. R. 60W. Goshen County, Wyoming.

Discussion. The pair of jaws is of an old individual hence the tooth characters have been obliterated. In size, proportions and general form, however, the specimen seems indistinguishable from *M. cooki* which has a marked range of variation. Normally in this species the first pair of inferior incisors is lost with age. The presence of these teeth in this specimen is, therefore, unusual.

Measurements

	mm.
Greatest length of mandible	398.0
Distance from mandibular condyle to anterior of jaw	388.0
Height of coronoid	210.0
Depth of mandible under center of P_4	53.5
Depth of mandible under center of M_3	69.0
Width of symphysis across caniniform incisors on alveoli	47.0
Length of symphysis	93.0
Length from P_2–M_3	164.5
Length from P_2–P_4	67.0
Length from M_1–M_3	101.0

Order ARTIODACTYLA

Suborder BUNODONTA

Superfamily DICHOBUNOIDEA

Family ENTELODONTIDAE

ARCHAEOTHERIUM PALUSTRIS sp. nov.

Type. Complete lower jaws without the teeth, M. C. Z. No. 2,980. Collected by Erich M. Schlaikjer, 1930.

Horizon and locality. Middle Oligocene. Brule formation, upper part of the middle oreodont zone. Harvard Fossil Reserve. Goshen County, Wyoming.

Specific characters. The largest known *Archaeotherium.* Symphysial region long, deep and very broad. Ramus proportionately slender. Posterior mental process long and nearly circular in cross section. P_1 very large and set close to P_2. No diastema between P_2 and P_3. M_1 reduced. (See Plate 20).

Description and discussion. A. palustris is an exceedingly large entelodont. The ramus is long and relatively slender. One of the more outstanding features is the very broad and extraordinarily massive symphysial region. The anterior mental process is missing but the base indicates that it was large, oval in cross section and projected downward and somewhat outward. Immediately above its anterior margin is a large mental foramen. None of the teeth are present but the alveoli and some of the roots are preserved. The incisors were very large and the canines enormous. P_1 was very large and there is no evidence that it was two-rooted. It was set close to P_2 and was separated from the canine alveolus only by a short diastema. P_3 and P_4 were large and subequal in size. The alveoli of M_1 are small which indicates that the tooth was considerably reduced. The coronoid process is very low and heavy. The condyle is large and faces backward. The masseteric fossa is oval-shaped, deep and extensive. The angle is heavy and very expanded. The vascular impression is well marked.

Of the described species of *Archaeotherium, A. palustris* is nearest to *A. scotti* Sinclair from the Chadron formation. Certainly the latter is the closest approach in size. *A. palustris* is different from this species, however, in the following characters: larger size; wider and heavier symphysis; premolar teeth more crowded and P_1 larger; ramus more slender; anterior mental process not flattened; and, the posterior mental process very much longer. Structurally, as well as stratigraphically, *A. scotti* is an ideal ancestor for *A. palustris.* Moreover, there is no evident reason why the latter could not be directly ancestral to *Boöchœrus,* the very large upper Oligocene form which can be considered as directly ancestral to *Dinohyus* of the lower Miocene. *Boöchœrus* is known only by the limbs. Mr. Peterson (1909, pp. 62–63) has shown that "Although *B. humerosus* is heavier than *D. hollandi,* the feet of the former are considerably shorter and broader than in the latter." He further states that, "The absence of an articular facet for metatarsal III on the lower tibial angle of the cuboid in the John Day form (*Boöchoerus*) is also a noticeable feature." It would seem, therefore, that from the Oligocene to the Miocene there was a change to a longer limbed form with a more firmly arranged tarsus. This development is in keeping with the changing environmental conditions of early Miocene times when the Great Plains region (the habitat of *Dinohyus*) was becoming more and more arid, and coincident with this the entelodonts, in the beginning primarily a rarian and palustrian group, were now compelled to adopt a cursorial habit. Their failure to fully achieve this was probably the very cause of their extinction later in the Miocene when environmental changes were even more severe.

Measurements

	mm.
Greatest length of the jaw	?
Width across jaws immediately posterior to anterior mental process	105.0
Width across jaws on exterior borders of canine alveoli	125+
Length of symphysis	175+
Width across posterior mental tubercles	270.0
Depth of jaw under M_3	104.0
Length of P_1–P_4	178.0
Length of M_1–M_3	105.0
Antero-posterior diameter of P_1 alveolus	35.0
Antero-posterior diameter of M_1 alveolus	29.5
Antero-posterior diameter of M_3 alvelous	38.0

ARCHAEOTHERIUM MORTONI Leidy

Material. An almost complete pair of lower jaws, M. C. Z. No. 2,914. Collected by Erich M. Schlaikjer, 1930.

Horizon and locality. Middle Oligocene. Brule formation, upper part of the middle oreodont zone. Harvard Fossil Reserve. Goshen County, Wyoming.

Discussion. This specimen is almost identical in size and characters with *A. mortoni* as figured and described by Mr. Peterson (1908), Mr. Troxell (1920) and Professor Sinclair (1921 and 1924). Its occurrence in the Harvard Fossil Reserve is of stratigraphic importance (as is also the occurrence of a number of other forms) since it is typically of the upper concretionary beds (middle oreodont zone of the Brule formation) in the Oligocene deposits of South Dakota.

DINOHYUS MINIMUS sp. nov.

Type. The symphysial region of the lower jaws with deciduous dentition, and the permanent teeth about to erupt, M. C. Z. No. 2,894. Collected by Erich M. Schlaikjer, 1932.

Paratype. P_2 and P_3, M. C. Z. Nos. 2,894a and b. Collected by Erich M. Schlaikjer, 1932.

Horizon and locality. Lower Miocene. Lower Harrison formation, *Promerycochoerus loomisi-Mesocyon hortulirosae* zone, approximately 200 feet above the Brule-lower Harrison contact. N.W.¼. Sec. 7. T. 20N. R. 60W. Goshen County, Wyoming.

Specific characters. About one-fourth smaller than *D. hollandi.* Incisors very large. Symphysis relatively expanded. (See Plate 21).

Discussion. This specimen possesses an excellent series of deciduous incisors. In their small size, narrow proportions and weakly developed cinguli these teeth resemble the permanent incisors of *Archaeotherium.* The lingual symphysial surface is broken away and the permanent incisors are seen ready to erupt. The first of these is approximately twice as large as DI_1. It has a heavy internal cingulum and is in a position as if it were going to replace both the first and second deciduous incisors. The second unerupted tooth is more caniniform than the first. It probably had an internal cingulum although this remains problematical since that portion of the tooth has been lost. The third tooth is the largest of the three. It is internal to and slightly behind the canine. DP_1 is small and is set close to the canine. Considerably behind it is the elongated and narrow DP_2. P_2 of the paratype differs from DP_2 in that it is shorter and heavier. P_3 of the paratype is about one third larger than P_2.

Dinohyus minimus is the smallest known member of this genus and its affinities are, of course, nearest *Dinohyus hollandi* the gigantic and only other known species from the lower Miocene.

Measurements

	mm.
Length of symphysis	150.0
Transverse diameter of DI_1	15.5
Transverse diameter of I_1	20.0
Transverse diameter of DI_2	23.0
Transverse diameter of I_2	20.5+
Transverse diameter of DI_3	22.0
Transverse diameter of I_3	20+
Antero-posterior diameter of C (at base of crown)	29.0
Transverse diameter of C	21.0
Antero-posterior diameter of DP_1	27.0
Transverse diameter of DP_1	14.5

Antero-posterior diameter of DP_2	34.0
Transverse diameter of DP_2	12.0
Width across canines (external)	131.5
Antero-posterior diameter of P_2 (paratype)	30.5
Transverse diameter of P_2 (paratype)	15.0
Antero-posterior diameter of P_3 (paratype)	41.0
Transverse diameter of P_3 (paratype)	20.0

Suborder ANCODONTA

Superfamily AGRIOCHOEROIDEA

Family OREODONTIDAE

CYCLOPIDIUS HETERODON Cope

Neotype. A fairly complete skull and jaws, M. C. Z. No. 2,849. Also referred to this species is an excellent skull and right lower jaw of an immature individual, M. C. Z. No. 2,826. Neotype collected in 1932 and the referred specimen in 1933 by Erich M. Schlaikjer.

Horizon and locality. Lower Miocene. Lower Harrison formation. Both specimens found approximately 110 feet above the Brule-lower Harrison contact. M. C. Z. No. 2,849 from S.E.¼. Sec. 17. T. 20N. R. 62W. and M. C. Z. No. 2,826 from S.E.¼. Sec. 22. T. 20N. R. 60W. Goshen County, Wyoming.

Characters. One of the smallest known species of *Cyclopidius*. Mesostyle, especially on M^1, very weakly developed. Molars very much laterally compressed and M^1 shortened. Premolars and molars greatly hypsodont. Incisors $\frac{2}{3}$. Lower incisors minute. Skull narrow for *Cyclopidius*. Facial area narrow and rather elongate. Orbits excessively large. Malar portion of the zygomatic arch not developed inferiorly. Antorbital fossae elongated, narrow and almost separated. (See Plates 22 and 23).

Description and discussion. The basicranial area is shortened and its axis is rather steep. The bulla is large and oval and has the hyoid and paroccipital processes deeply embedded in it. On the anterior surface of the bulla there is a barb-like projection which is in contact with the pterygoid. When viewed from behind the skull is quadrate in outline. The lambdoid crest is low and the sagittal crest is only pronounced posteriorly. The postorbital bar (incomplete in a young individual) is weakly developed and the orbits are proportionately very large. The upper and lower incisors of the neotype are not preserved. There are two incisor alveoli preserved, however, in the lower jaw and it is probable that the third, which is more shallow, has been broken away. There is no reason for assuming that the incisor formula of the neotype is different from that ($I\frac{2}{3}$) of specimen M. C. Z. No. 2,826 which is so exactly similar in all of its other important characters. It must also be borne in mind that the incisor alveoli of *Cyclopidius* are shallow and when even a small amount of the superior symphysial area is broken away all evidences of incisors may be completely obliterated. This is particularly true of old individuals and is admirably shown in specimen M. C. Z. No. 2,842 (See Plate 22) which is unquestionably *C. heterodon.*

The outstanding features of the cheek teeth are: their very hypsodont development; the transverse compression of the molars; the shortened M^1; and, the weak development of the styles on the molars.

In 1878 Professor E. D. Cope (P. 222) described the species *Cyclopidius heterodon* which he based on a fragmentary maxilla containing P^4 and M^1. In 1884 (P. 559) he referred this species to the genus *Pithecistes.* Later on Matthew (1899, p. 73) restudied the Cope specimens and rightfully concluded that *Pithecistes* was a synonym for *Cyclopidius.* He stated, however, that in *C.* (*P.*) *brevifacies* "there are no distinctions whatsoever from *Cyclopidius simus* except those due to age of the individual." After a carefuly study of the material in the American Museum I am convinced that *C.* (*P.*) *brevifacies* is a very short and deep-jawed form which is specifically distinct from *C. simus* Cope. Matthew further stated that, "*Pithecistes decedens* is the permanent and *P. heterodon* probably the milk dentition of a smaller species of *Cyclopidius.*" Close inspection of the type of *C. decedens* (consisting of a maxilla with three teeth) reveals that the teeth present are DP^{3}-^{4} and M^1 and that this species can, without question, be referred to *C. simus* as suggested by Loomis (1925, p. 248). *C. heterodon,* as is now shown by the Goshen Hole material, is a valid species and the two teeth of the type are the permanent P^4 and M^1.

This rare little *Cyclopidius* is a species which seems to represent a dwarf line that evolved from some species of *Leptauchenia,* perhaps from *L. nitida* itself, in later Oligocene times. Dr. Chester Stock (1930, p. 38–39) has described, from the lower Miocene Sespe deposits of California, the smallest known form of the *Leptauchenia-Cyclopidius* group which he regarded as "*Leptauchenia?* (*Sespia*) *californica* n. subgen. and sp." The characters listed for this new subgenus are as follows (p. 38): "Skull with large antorbital vacuities; nasals long and narrow; ramus of mandible relatively deep. External styles on upper molars less developed than in *Leptauchenia.* Styles on inner walls of lower molars feebly developed or absent. M_3 with inner wall of posterior lobe projecting but slightly past the inner wall of the middle lobe. No overlapping of inner enamel wall of middle lobe by inner wall of anterior lobe in M_3." All of these characters are prevalent in *C. heterodon* and the main distinguishing feature between these two species is one of size. No incisors were preserved in the California specimen and Dr. Stock very tentatively referred it to *Leptauchenia.* Since its close affinities to *C. heterodon* are now established it can be referred to the genus *Cyclopidius,* and on the basis of the known material, affords an ideal ancestral stage, structurally at least, for *C. heterodon.* (See Fig. 11). The discovery of *C. californica* is of particular interest since it is the first record of occurrence of the *Leptauchenia-Cyclopidius* group west of the Rocky Mountains.

Measurements

	mm.
Skull length, lambdoid crest to premaxillary	89.0
Length of dental series, C-M^3	44.0–48.0
Length of superior premolars	18.0–19.0
Length of superior molars	23.0–25.5
Length of inferior premolar-molar series	44.5
Greatest length of mandible	74.0

CYCLOPIDIUS DENSA (Loomis)

Material. Two excellent adult skulls and jaws, M. C. Z. Nos. 2,850 and 2,866, two skulls of young individuals, M. C. Z. Nos. 2,876 and 2,877, two palates M. C. Z. Nos. 2,067 and 2,851 and a number of isolated jaw fragments and teeth. (See Plates 24 and 25). Collected by Erich M. Schlaikjer, 1931–1933.

Horizon and locality. Lower Miocene. Lower Harrison formation. Goshen County, Wyoming.

Discussion. Dr. Loomis described (1925) a new species of *Leptauchenia* from the lower Harrison (lower Rosebud) at Muddy Creek, eastern Wyoming which he named *L. densa* and to which species he referred a large number of skulls from the same beds and from the lower Harrison of the Goshen Hole Area. He recognized the many *Cyclopidius*-like characters in this species, however, but referred it to *Leptauchenia* principally because it possessed three lower incisors for later he stated,[1] "In my material the question of 2 or 3 incisors in the upper jaw is not clear. I assumed that if there were 3 below — there were 3 above." The question of generic distinctions between *Leptauchenia* and *Cyclopidius* has not been definitely settled. Dr. Thorpe (1921, p. 412–413) reviewed the subject and concluded that, "If we assume for the present at least that *Cyclopidius* has but two incisors in each tooth row, then we have the most marked generic distinction between this genus and *Leptauchenia,* which has the full complement of forty-four teeth." A study of the *Cyclopidius* types and a large number of other specimens shows that wherever the incisors are preserved the formula is $I\frac{2}{3}$. One possible exception to this is seen in *C. brevifacies* which is founded on a lower jaw. In this species only two incisor alveoli are present. Since, however, the jaw is that of a very old individual and since the alveoli present are minute and very shallow, it is entirely possible that the loss of one of the incisors is an old age character,— a condition not infrequent among other groups of mammals. Nevertheless, it would not be surprising to find a species of *Cyclopidius* with less than three or, as suggested by Thorpe, even no inferior incisors. The fact of importance is that *Cyclopidius* may, and usually does have three lower incisors. All of the Goshen Hole specimens at the Museum of Comparative Zoölogy which can be referred unquestionably to *Leptauchenia densa* have three lower and two upper incisors. This condition together with the many other "typical" *Cyclopidius* characters such as the proportionately shortened skull, the massiveness of the malar portion of the zygomatic arch and the deep and heavy mandible, show that *L. densa* should be placed in this genus. It is curious that of the lower incisors I_2 is smaller than I_1 or I_3. It would seem, therefore, that the superior incisor which has been lost is I^2. Also, if *C. brevifacies* has but two lower incisors, it is probable that the second rather than either the first or the third has been lost. This is a most unusual character and one which is to be found only in a very few groups of mammals.

In size, *C. densa* is about the same as that of *C. simus* although its molar series is proportionately much longer and in this, as well as in several other characters, it is intermediate between this species and *C. lullianus,* the largest known member of this genus and one which is found in the same beds.

There seems to be a marked amount of variation in the species of *C. densa.* For example, two specimens M. C. Z. Nos. 2,067 and 2,851 (see Plate 25) were found at exactly the same level and only a few feet apart. The former is unmistakably *C. densa.* No. 2,851 differs from this specimen principally in that it is somewhat larger and more robust and in the greater development of the internal crest on P^3. An evaluation of these features as specific characters seems unwarranted. They may be accounted for merely as sex differences. Moreover, that No. 2,851 is a hybrid of *C. densa* and the large and more specialized form *C. lullianus* which occurs in the same beds, is not improbable.

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[1] Communication by letter.

Another significant feature, shown in the material at hand, which is present in this species and which is likely to hold true, when more complete material is known, for all the other species and perhaps for *Leptauchenia* as well, is the change in skull proportions in young and old individuals. Three specimens in the Harvard collection, one, No. 2,876, a very young individual with only the first of the molar teeth in permanent position, another, No. 2,877, with the first two molars in permanent position, and a third, No. 2,866, which is a rather old individual, show that from youth to old age the skull becomes more brachycephalic (see Table 4).

	M.C.Z. No. 2876 very young	M.C.Z. No. 2877 young	M.C.Z. No. 2866 rather old
Greatest length of skull	108	133	140
Width across malar arches	70	94	102
Cephalic index	.648	.707	.728

TABLE 4. Comparative skull measurements and cephalic indices of three specimens of *Cyclopidius densa.*

Not only in skull proportions is there a change from youth to old age, but the skull in general seems to become heavier in its construction. This is especially true of the malar arches and of the sagittal and lambdoid crests. Likewise, in the dental series marked changes take place with age. For example, each molar tooth is sphenoidal in outline,—that is, toward the base of the crown the antero-posterior dimension diminishes while the transverse dimension increases. Therefore, as the tooth is worn it becomes broader and shorter. Also, in some species (ex. *C. heterodon*) the metaconule is smaller and the protocone is larger at the base of the crown, thus the former becomes smaller and the latter larger with wear. It would seem probable that a prevalence of these features will also be found in *Leptauchenia.*

LEPTAUCHENIA MINORA[1]. sp. nov.

Type. The palate of a young individual with I^3, P^1, DP^{2-4} and M^{1-2}, M. C. Z. No. 2,841. Collected by Erich M. Schlaikjer, 1932.

Horizon and locality. Lower Miocene. Lower Harrison formation, approximately 200 feet above the Brule-lower Harrison contact. N.W.¼. Sec. 36. T. 20N. R. 62W. Goshen County, Wyoming.

Specific characters. The smallest known *Leptauchenia,*— about one fifth smaller than *L. nitida* of the upper Oligocene. Molars proportionately long and transversely constricted. Styles not greatly developed. Mesostyle reduced and does not overlap the external wall of the paracone. Palate relatively narrow. Alveolar portion of the premaxillae more reduced and the incisors smaller than in *L. nitida.* (See Plate 41).

Discussion. Since it has been shown that *Leptauchenia? (Sespia) californica* Stock and *Leptauchenia densa* Loomis belong to the genus *Cyclopidius,* there are only three species which can be referred to *Leptauchenia.* They are *L. nitida* Leidy, *L. decora* Leidy and *L. major* Leidy. The first two are unquestionably from the upper Oligocene and the latter is either upper Oligocene or lowermost Miocene in age. The new species named above adds a fourth to the list and cannot be confused with any of the others because of its size, the compressed molars, the reduced mesostyle and the reduced incisors.

The deciduous premolars three and four differ from those of *Cyclopidius* principally in being less molariform. The posterior portion of DP^3 is not nearly so transversely expanded and the internal cusps of DP^4 are more rounded. In *Cyclopidius* DP^4 is completely molariform. (Dr. Loomis, 1925, p. 246, Figure 4, in his drawing of the deciduous premolars of *C. densa* designates, through a *lapsus pennae,* DP^3 as DP^4).

On first appearance it would seem that the small mesostyle and the compressed molars are primitive characters. It is more probable however, that these are specializations since they are expressed even to a greater degree in *C. heterodon.* The reduction of the alveolar portion of the premaxillae with the small and very crowded incisors is a further specialization in the *Cyclopidius* direction. Of the known forms, the nearest relative of *L. minora* is *L. nitida,* from which species it could have been derived,— or possibly from an earlier and more primitive species. It represents the last known form of this upper Oligocene genus existing on into the early Miocene. (See Figure 11).

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[1] From the Latin meaning "little one."

Measurements

	mm.
Length of dental series I^3–M^2	46.2
Length of P^1 to P^4 (deciduous)	22.3
Length of M^1 to M^2	20.0
Greatest length of M^1	9.9
Greatest length of M^2	11.6
Width across the canines	14.1
Width across the first superior molars	32.0

LEPTAUCHENIA and CYCLOPIDIUS

As stated above, four species are now assigned to Leidy's genus *Leptauchenia.* Of these *L. nitida* is the most primitive, *L. major* the most specialized and *L. decora* is an admirable intermediate form between these two species. Although all three forms occur in the same beds such a phylogenetic arrangement is probable. *L. minora* is a small rather specialized species which lived in early Miocene times and which probably had *L. nitida* as its direct ancestor. These relationships are graphically illustrated in Figure 11.

There has been considerable discussion concerning the validity of the various species referred to the genus *Cyclopidius.* Dr. Matthew (1899, p. 73) considered *C. brevifacies* (Cope) as synonomous with *C. simus* Cope. He also regarded *C. decedens* (Cope) as the permanent and *C. heterdon* (Cope) as the milk dentition of a smaller species. In 1925 Dr. Loomis (p. 248) held that all of these species belong to *C. simus.* All of this material was collected in the lower Miocene, lower Deep River beds of Montana. The Goshen Hole specimens aid greatly in clarifying this problem. As shown previously, *C. heterodon* is unquestionably a valid species. Of the three upper teeth preserved in the type of *C. decedens* the second is the very molariform DP^4 and not M^1 as suggested by Professor Cope and Dr. Matthew. This type is therefore, only a young individual of *C. simus. C. brevifacies* is a short, broad and deep-jawed form which certainly cannot be referred to any of the other species. It is not improbable that when the skull is known, *C. shucherti* Thorpe,— the short and very broad-skulled form, may be referable to this species.

In 1884 Professor Cope described *C. emydinus,* (Amer. Mus. No. 8,115) a splendid skull of an old individual, from the same beds as *C. simus* but considered it as distinct from this species in the following characters which he listed (p. 553): "First, the external vertical ridges or crests of the true molars are directed obliquely forwards so as to overlap the external wall of the anterior crescent much more extensively than in *C. simus.* (2) The crown of the true molars have a relatively greater transverse diameter. (3) There is a peculiar process at the external base of the otic bulla, between the paroccipital and postglenoid processes, which may be called the subtympanic process. (4) There is no median occipital keel. (5) The maxillary bone is prolonged posterior to the last superior molar, which is not in *C. simus.* (6) The oblique orbitosphenoid ridge is wanting. (7) The otic bullae are shorter and wider in their form. This character will require confirmation by examination of many individuals." Both of these specimens are in the American Museum and recently they were further prepared,— thus allowing a closer comparison to be made. Dr. Walter Granger, through the courtesy of the Department of Vertebrate Palaeontology has permitted me to reexamine these types and has supplied me with photographs so that *C. simus,* the genoholotype could be illustrated. (See Plate 26). After a careful inspection of both types, I am unable to observe any character or characters in *C. emydinus* which distinguish it specifically from *C. simus.* A reconsideration of the seven characters listed by Professor Cope may be summarized as follows:

1. The anterior projection of the mesostyle becomes greater near the base of the tooth crown. The teeth of *C. emydinus* are more worn than those of *C. simus,* hence the mesostyles seem more developed.
2. As stated previously, with wear the molar teeth become shorter (anteroposteriorly) and broader. This, together with a small amount of variation in the species, accounts for the "relatively greater transverse diameter" of the molars.
3. The "subtympanic process" is the hyoid process which is partially embedded in the bulla. It is present in *C. simus* as well as in all species of this genus.
4. The absence of a median occipital keel seems to be an old age character coincident with a rugose and heavy development of the lambdoid crest.
5. A prolongation of the maxilla behind M^3 might also be accounted for as an old age character, or an individual variation.
6. The "orbitosphenoid ridge" is faintly present in both, a seeming emphasis of it in *C. simus* was due to crushing.
7. There is little, if any, difference in the dimensions of the bullae in the two species. In *C. simus* the bulla is somewhat transversely crushed.

Dr. Loomis (1925, p. 248) has rightfully regarded *C. incisivus* Scott, also from the lower Deep River beds, as belonging to *C. emydinus*, which of course, in the light of the above interpretation, is equivalent to *C. simus*.

	Geological formation	Skull length	Length of Pms.	Length of Ms.
L. nitida Leidy	Upper Brule	88.9–100.0	15.8–22.0	20.1–25.0
L. decora Leidy	Upper Brule	101.6–110.0	14.8–20.0	29.6–31.7
L. major Leidy	Upper Brule?	139.0–146.0	25.4–35.0	40.2–42.3
L. minora sp. nov.	Lower Harrison	?	?	?
C. lullianus Thorpe	Lower Harrison	144.0	30.5	44.2
C. densa (Loomis)	Lower Harrison	123.0–134.0	25.0–27.0	–45.0
C. simus Cope	Lower Harrison (Lower Deep River beds)	126.8–129.8	24.0–25.0	33.5–35.5
C. schucherti Thorpe	Lower Miocene (Lower Harrison?)	?	20.0	28.5
C. brevifacies (Cope)	Lower Harrison (Lower Deep River beds)	?	?	?
C. heterodon Cope	Lower Harrison	89.0	18.0–19.0	23.0–25.5
C. californica (Stock)	Lower Miocene (Lower Harrison?)	?	15.6	?

TABLE 5. A list of the species of *Leptauchenia* and *Cyclopidius* with the geological level and three salient measurements of each.

The species of *Leptauchenia* and *Cyclopidius* which, for the present, may be regarded as valid are listed in Table 5.

In Figure 11 is given a tentative phylogeny of all the known species of *Leptauchenia* and *Cyclopidius*. This is primarily intended to show structural relationships. Little is known of the ancestry of these two genera. Of the scanty remains described from the early Oligocene deposits, *Limnentes* Douglass seems, as regarded by Loomis (1924a, p. 15), to be the most likely ancestor, although, when more completely known, it may be found to be nearer the *Eporeodon* line.

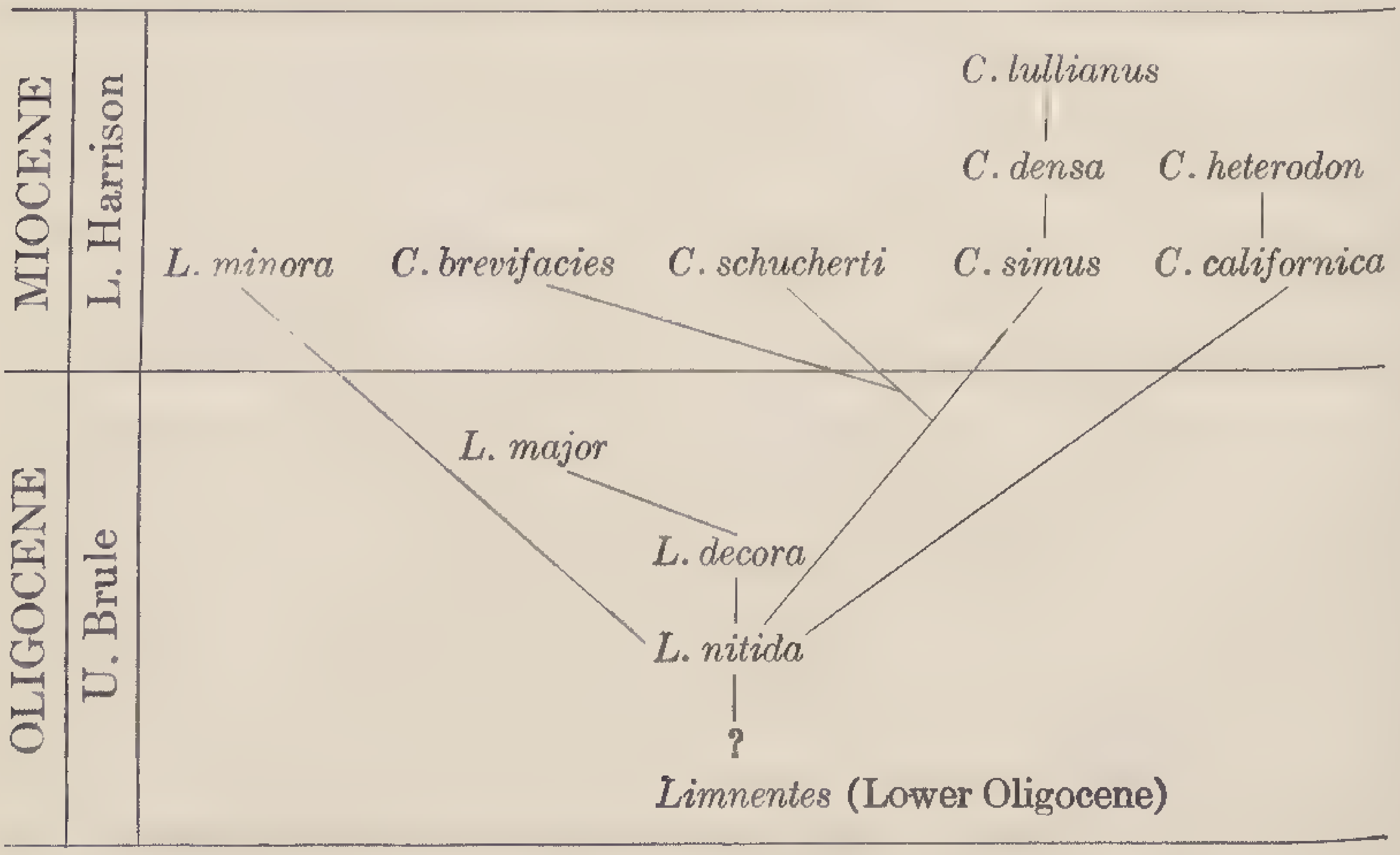
MIOCENE
L. Harrison
OLIGOCENE
U. Brule
C. lullianus
C. densa
C. heterodon
L. minora
C. brevifacies
C. schucherti
C. simus
C. californica
L. major
L. decora
L. nitida
?
Limnentes (Lower Oligocene)

FIG. 11. Phylogenetic chart of the species of *Leptauchenia* and *Cyclopidius*. Schlaikjer 1934.

A study of the skulls in particular of the *Leptauchenia-Cyclopidius* group of oreodonts reveals a number of important facts of which the following are the outstanding:

1. The molar teeth are sphenoidal in general form,— that is, the anteroposterior dimension is less and the transverse dimension is greater near the base of the crown.
2. With wear, therefore, the molar teeth become proportionately shorter and broader.
3. There is considerable variation in the premolar teeth, especially in P^3.
4. The incisor roots are frequently short, particularly those of I_{1-2}, and when only a small amount of the superior portion of the symphysis is broken away some or all of the alveoli may be destroyed.
5. It appears that with age the skull becomes more brachycephalic.
6. There is a considerable variability in size which may be accounted for primarily as a sex difference. The somewhat larger and more heavily built skulls are probably those of males.

A careful consideration of these facts, before new species are described, would certainly seem advisable.

MERYCHYUS HARRISONENSIS Peterson

Material. Left maxilla with P^2–M^3 and the root of P^1, M. C. Z. No. 2,869. (See Plate 41). Collected by Erich M. Schlaikjer, 1932.

Horizon and locality. Lower Miocene. Lower Harrison formation, approximately 125 feet above the Brule-lower Harrison contact. N.E.¼. Sec. 29. T. 25N. R. 64W. Goshen County, Wyoming.

Discussion. The teeth of this specimen, in size and even in the stage of wear, are identical with those of Peterson's type (1906, p. 37–40). One of the more important features of the dental series is the rather elongated P^3 with a strong anterior intermediate crest which divides the front part of the tooth into two basin-like areas. There is also present a weakly developed median crest. This dental character is one which seems more typical of the genus *Ticholepus* rather than of *Merychyus*. Dr. Loomis (1923, p. 227) has referred this species to the former genus mainly on the basis of size and skull proportions. *M. harrisonensis* is, however, smaller than the "typical" *Ticholepus*. Then too, the dental series is shorter than that of such species as *M. arenarum* Cope and *M. siouxensis* Loomis. For the present, therefore, I choose to retain this species in the genus *Merychyus*. The occurrence of this species in the lower Miocene Beds of the Goshen Hole Area is of significance since it adds to the other corroborative evidence which substantiates the correlation of these beds with the lower Harrison of northwestern Nebraska.

Measurements

	mm.
Length of the premolars	37.0
Length of the molars	44.5
Length of P^2	10.0
Length of P^3	9.5
Width of P^3	8.0
Length of P^4	8.6
Width of P^4	11.5
Length of M^1	12.0
Width of M^1	13.5
Length of M^2	15.0
Width of M^2	15.0
Length of M^3	20.0
Width of M^3	16.1

MERYCHYUS MINIMUS Peterson

Material. Right mandible with P^1–M^3, M. C. Z. No. 2,868. Collected by Erich M. Schlaikjer, 1934.

Horizon and locality. Lower Miocene. Lowermost upper Harrison formation, approximately 500 feet above the Brule-lower Harrison contact. S.E.¼. Sec. 3. T. 24N. R. 65W. Goshen County, Wyoming.

Discussion. This specimen is that of a mature yet fairly young individual and it corresponds in almost every respect with the type of *M. minimus* Peterson from the upper Harrison formation of Sioux County, Nebraska and is, therefore, of stratigraphic importance. It was found at exactly the same level as *Parahippus wyomingensis* which is also an upper Harrison form.

Measurements

	mm.
Height of mandible at coronoid process	73.0
Depth of mandible at anterior of M_3	26.0
Length of lower premolars	30.0
Length of lower molars	44.0

EPOREODON CHEEKI Schlaikjer

Material. A nearly complete skeleton, the type, M. C. Z. No. 17,765. (See Plates 27, 28 and 29). The skeleton of a young individual M. C. Z. No. 2,867, and an immature skull and jaws, M. C. Z. No. 2,870. Collected by Erich M. Schlaikjer, 1932–1933.

Horizon and locality. Lower Miocene. Lower Harrison formation. Goshen County, Wyoming.

Discussion. The type was fully described by Schlaikjer (1934, p. 220–223) and is now figured in Plates 27, 28 and 29. As pointed out previously, *E. cheeki* is the last known survivor of this genus existing as a living fossil in the early Miocene along with such genera as *Mesoreodon* and *Promerycochoerus* that are descendants of the upper Oligocene members of this genus.

MESOREODON CHELONYX Scott

Material. An excellent skull, M. C. Z. No. 2,814 (see Plate 30), and two jaws M. C. Z. Nos. 2,819 and 2,824. Collected by Erich M. Schlaikjer, 1932.

Horizon and locality. Lower Miocene. Lower Harrison formation. M. C. Z. No. 2,814 from Bear Creek Mountain and M. C. Z. Nos. 2,819 and 2,824 from 66 Mountain, Goshen County, Wyoming.

Discussion. This material is practically identical with the type as described and figured by Professor Scott (1893). The occurrence of this species, as well as such forms as *Cyclopidius simus* and *C. heterodon,* in the lower Harrison formation of the Goshen Hole Area is significant since it shows that these deposits (as stated earlier in this paper) can be considered as of the same age as the lower Deep River beds of Montana.

MESOREODON MEGALODON Peterson.

Material. A complete skull and jaws, adult, M. C. Z. No. 17,751. (See Plate 31). A pair of jaws M. C. Z. No. 2,822 and the jaws of a young individual M. C. Z. No. 2,817. Collected by Erich M. Schlaikjer, 1932–1933.

Horizon and locality. Lower Miocene. Lower Harrison formation. M. C. Z. No. 17,751 from approximately 200 feet above the Brule-lower Harrison contact. S.E.¼. Sec. 21. T. 20N. R. 60W. M. C. Z. No. 2,822 from the same level at Fox Creek Gap. M. C. Z. No. 2,817 found at the same level and a few feet away from the type of *Hypohippus avus,* approximately 100 feet above the Brule-lower Harrison contact. S.W.¼. Sec. 16. T. 20N. R. 63W. Goshen County, Wyoming.

Discussion. The type of *Mesoreodon megalodon* Peterson consists of the front of a skull and jaws collected from the "Monroe Creek beds",— lower Harrison of Sioux County, Nebraska. Dr. Loomis (1933, p. 727) has referred a skeleton to this species from the lower Miocene (lower Harrison) beds at Muddy Creek in eastern Wyoming, as well as several skulls and considerable limb material from 66 Mountain in Goshen Hole. The material in the Harvard Museum corresponds identically with Peterson's type. This material occurs at the same level as *Merychus harrisonensis* a typical lower Harrison species and is additional evidence, therefore, as suggested in the stratigraphic section of this paper, that the Monroe Creek and lower Harrison beds are synchronous deposits.

MESOREODON SCOTTI Schlaikjer

This species was based on a nearly complete skeleton, M. C. Z. No. 17,480 (1934, p. 223–225) and is figured in Plate 32 of this paper. The specimen was collected by Dr. F. B. Loomis from the lower

Harrison formation at Muddy Creek, Wyoming. No specimens referable to this species have as yet been found in the Goshen Hole Area. Nevertheless, at Muddy Creek *M. megalodon* occurs in the same beds, and it, as well as *M. chelonyx*, is also found in the lower Harrison of Goshen Hole. All three species, therefore occur at the same geological level yet they form an excellent evolutionary sequence, structurally, in this genus with *M. chelonyx* the most primitive, *M. scotti* the intermediate and *M. megalodon* the most advanced species.

PROMERYCOCHOERUS LOOMISI Schlaikjer

The type of this species is an excellent skeleton, M. C. Z. No. 2,820, which was collected from the lower Harrison formation, Bear Creek Mountain, Goshen County, Wyoming. It is figured in Plates 33–35 of this paper. As stated previously (1934, p. 225–229) *P. loomisi* is a large-skulled, short bodied and long-limbed form. The more outstanding features of this species are: the very large and narrow skull, the large but short body and the relatively long limbs. It is an excellent example of gigantism among the oreodonts. *P. grandis* may be considered its direct ancestor and since the smaller and more primitive species *P. hatcheri* occurs in the same beds it would seem that *P. loomisi* represents a very progressive evolutionary line of *Promerycochoerus.*

PROMERYCOCHOERUS HATCHERI Douglass

Material. An excellent skull, M. C. Z. No. 2,815 (see Plates 36, and 37). A skull and jaws with atlas, axis, two cervicals and an astragalus, M. C. Z. No. 17,760 (see Plate 38). A skull and jaw, M. C. Z. No. 2,816, two pairs of jaws, M. C. Z. Nos. 2,821 and 2,825 and the skull and jaws of an old invididual, M. C. Z. No. 2,816. Collected by Erich M. Schlaikjer, 1932–1933

Horizon and locality. Lower Miocene. Lower Harrison formation. M.C.Z. Nos. 2,815, 17,760, 2,816, 2,821, and 2,825, from the *Eporeodon cheeki-Mesoreodon megalodon* level 66 Mountain, M. C. Z. No. 2,816 from the same level on Bear Creek Mountain, Goshen County, Wyoming.

Discussion. The type of this species was collected from the lower Deep River Beds, Montana, and was briefly described by Douglass, 1907. The dental series was not figured by Douglass but so far as can be judged from his description and figure of the skull the Harvard specimens are almost identical with the type except for the smaller size and the slightly more posterior position of the infraorbital foramen, which characters I regard as individual variations. A typical *Promerycochoerus* dental character is the separation of the internal crescent from the median crest in P^3. The pattern of this tooth is primitive, however, in that the posterior crest is not united posteriorly with the posterior crescent (see Plate 37). The dental and cranial feature of this species are structurally intermediate between *Eporeodon cheeki* and *Promerycochoerus loomisi* all of which occur at exactly the same geological level.

There appears to be a considerable amount of variation in this species. M. C. Z. No. 17,760 (see Plate 38), for example differs from M. C. Z. No. 2,815 (see Plates 36 and 37) only in its somewhat smaller size and lighter construction. These differences are probably sexual,— No. 17,760 being the skull of a female.

Measurements

	M.C.Z. 2,815 ♂	M.C.Z. 17,760 ♀
Greatest length of the skull	280.0	263.0
Condylo-basal length	246.0	240.0
Greatest breadth across squamosals on malar arches.	156.0	?
Length of dental series (C-M^3 inclusive)	133.0	129.0
Length of dental series (P^1–M^3 inclusive)	118.0	114.0
Distance from P^1 to P^4 external	55.0	52.
Distance from M^1 to M^3 external	69.0	?

MERYCOIDODON CULBERTSONI (Leidy)

Of all the fossil mammals which occur in the middle Oligocene deposits of South Dakota and Nebraska, *Merycoidodon culbertsoni* is by far the most numerous. Yet, in the Goshen Hole Area with its extensive and abundantly fossiliferous middle Oligocene only a single fragmentary skull and a few isolated teeth were found. This may be accounted for by the fact that the oreodonts were gregarious and extremely localized in their distribution.

Suborder TYLOPODA

Superfamily CAMELOIDEA

Family CAMELIDAE

MIOTYLOPUS BATHYGNATHUS gen. et sp. nov.

Type. A partial skull and jaws and an associated pelvis with most of the sacrum, M. C. Z. No. 2,924. Collected by Erich M. Schlaikjer, 1932.

Horizon and locality. Lower Miocene. Lower Harrison formation, approximately 150 feet above the Brule-lower Harrison contact. N.E.¼. Sec. 20. T. 20N. R. 60W. Goshen County, Wyoming.

Generic characters. Orbit incompletely closed. Tympanic bullae relatively small. Molars brachyodont, relatively small and without mesostyles, except a faint indication of one on M^3. Postcranial skeleton, as indicated by the pelvis, probably proportionately small and of light construction.

Specific characters. Inferior premolars simple. P_1 separated from the canine by a long diastema which is subequal to that which separates P_1 from P_2. Styles on inner walls of inferior molars absent or feebly developed. Ramus narrow and relatively deep. Infraorbital foramen above the paracone of M^1. Interorbital breadth across frontals very great. (See Plate 39).

Description and discussion. In the basicranial area there are a number of rather unusual features. The basicranial axis has a very gentle slope. The basioccipital is wide, has a short median crest on either side of which is a large and shallow depression which is bounded laterally by a low sharp ridge. Where the basioccipital and basisphenoid unite there are two elongated, prominent and rugose protuberances developed. The left and the posterior part of the right palatine and most of the pterygoids are broken away. Posteriorly the latter are widely separated. The tympanic bulla is relatively small,—actually not any larger than that of *Poëbrotherium* yet the skull is almost twice as large as that of the latter. It possesses only a shallow posterior vertical groove. This is in marked contrast to the deep ravine-like invagination of the bulla of *Poëbrotherium, Paratylopus* and *Oxydactylus*. The paroccipital processes are narrow and short. They project backward and considerably overhang the very deep and rounded condyloid fossae. There are two hypoglossal foramina in the left fossa and one in the right. This difference in number seems to be a variable character among the Artiodactyla.

The occipital condyles are low and are relatively very broad. The articular surface of the ventral portion is approximately one third greater than the dorsal surface. Ventrally the condyles are separated by a shallow groove. The supraoccipital is low. Ventrally it is transversely convex and dorso-medially it presents a strong crest. The lambdoid crest and the posterior part of the sagittal crest are strongly developed.

The postorbital region is proportionately long and the cranium is broad. The frontals are fairly short, but very wide especially between the orbits. The postorbital process is incompletely preserved although the position and unusual thinness of the considerable portion which is preserved shows, together with the gentle curvature of the malar border, that the orbit was probably not completely closed. Although the facial region is missing, the jaws indicate that it was relatively short, narrow and probably not expanded across the alveolar portion of the premaxillaries. The antero-external margin shows that the antorbital vacuity is of moderate size. The lacrimal forms the upper half of the anterior margin of the orbit and extends far forward on the face. The facial crest is low and knob-like. The infraorbital foramen is above the center of the M^1 paracone. The palate is very narrow as is shown by the preserved portion of the right maxillary and palatine.

The jaws are narrow and the symphysis is short and steep. Even though the individual was fully adult the rami are not firmly united. The ramus is long, very narrow and exceptionally deep especially under P_1. Its inferior margin is almost straight. The infraorbital foramen is large and is situated under the anterior of P_1.

The rather complete pelvis and sacrum associated with the type, and probably from the same individual, shows that in comparison with the skull, the postcranial skeleton was proportionately small. The small size of the acetabulum would indicate a rather slender-limbed form.

Compared with the other genera of camels from the lower Miocene, *Miotylopus bathygnathus* shows no close affinity with any of the known forms. The open orbit, the relatively small bullae and the low-crowned almost styleless molars are *Poëbrotherium*-like, while the relatively short face and large cranium, the deep ramus and the simplified inferior premolars are habitus characters. In the absence or feeble development of styles on the inner walls of the inferior molars, this form is close to *Paratylopus sternbergi* of the John Day; and in the simplified inferior premolars it is close to *Protomeryx,* also of the upper Oligocene. These seem to be characters of convergence, however, since in the large assemblage of other characters, *Miotylopus bathygnathus* is so strikingly different from either of these two genera.

Recently the writer had the privilege of inspecting a fine camel skull which was collected by Dr. Chester Stock from the lower John Day of the Sespe. This specimen is genericly distinct from *Miotylopus* and will soon be described by Dr. Stock as a new genus. It possesses a number of characters which seem intermediate between *Poëbrotherium* and *Miotylopus* and may be the upper Oligocene progenitor of the latter.

Measurements

	mm.
Condylo-basal length of skull (estimated)	220.0
Length of M^1–M^3	41.8
Length of inferior dental series C-M_3	115.0
Length of inferior premolars	50.7
Length of inferior molars	48.5
Distance from P_1–P_2	18.2
Depth of jaw under P_1	18.5
Depth of jaw under P_2	23.0
Interorbital breadth across frontals	71.6
Breadth across squamosals on cranium	56.8
Width of occipital condyles	36.0
Antero-posterior diameter of acetabulum	24.0
Length of pelvic symphysis	80.0

STENOMYLUS HITCHCOCKI Loomis

Material An excellently preserved posterior portion of a skull and jaws with $M\frac{3}{3}$, M. C. Z. No. 2,925. Collected by Erich M. Schlaikjer, 1931.

Horizon and locality. Lower Miocene. Lower Harrison formation, approximately 24 feet above the Brule-lower Harrison contact. S.W.¼. Sec. 36. T. 20N. R. 62W. Goshen County, Wyoming.

Discussion. This specimen is almost identical with the type of *S. hitchcocki* which was collected from the famous *Stenomylus* quarry four and one half miles east of Agate, Nebraska. It differs from the type specimen only in a somewhat longer saggital crest and in a slightly wider and shorter M^3. Also, the mandible is somewhat more shallow under M_3. These differences are of little significance, however, since this species displays a considerable amount of variability, as is shown in the many skeletons collected from the same quarry as the type. For example, one of these skeletons in the American Museum, No. 14,227, shows the same variations from the type as does the Goshen Hole specimen.

Stenomylus, in so far as is known, is a lower Harrison genus and the occurrence of *S. hitchcocki* in the Goshen Hole Area is of particular importance stratigraphically.

PROTOMERYX sp.

The writer has been informed by Dr. Frederick Brewster Loomis that in 1927 some local people discovered a nearly complete skeleton of *Protomeryx* in the lower Harrison beds on 66 Mountain. The specimen was collected and presented to the University of Wyoming Museum. Recently Dr. Loomis inspected the specimen and found it to represent a new species. It has been turned over to him for study and a description of it is soon to appear.

It is probable that two specimens, M. C. Z. Nos. 17,763 and 2,068, both of which are the facial portions of skulls of young individuals, belong to the same species as the above. They were found by the writer in the same beds and in the same locality. They have been turned over to Dr. Loomis for study.

OXYDACTYLUS sp.

Collected in the same block of sandstone containing the skeleton of *Parahippus wyomingensis* (see above) was an almost complete left front foot of *Oxydactylus,* M. C. Z. No. 17,762. The metacarpals are approximately thirty millimeters shorter than those of *O. brachyodontus* Peterson. During the past field season the writer collected an unusually complete skull and jaws and partial skeleton from the same beds. This individual has an especially short skull and a relatively long premolar-series. It is undoubtedly a new species and when it is prepared for study it will be fully described in a subsequent paper. It is probable that the above mentioned foot is referable to the same species.

Suborder PECORA

Superfamily TRAGULOIDEA

Family HYPERTRAGULIDAE

NANOTRAGULUS INTERMEDIUS sp. nov.

Type. The skull and jaws of an immature individual, M. C. Z. No. 2,103. Collected by Erich M. Schlaikjer, 1931.

Horizon and locality. Lower Miocene. Lower Harrison formation, approximately 200 feet above the Brule-lower Harrison contact. N.W.¼. Sec. 36. T. 20N. R. 62W. Goshen County, Wyoming.

Paratype. An adult skull with the right maxilla and teeth missing, M. C. Z. No. 2,812. Collected by Erich M. Schlaikjer, 1933.

Horizon and locality. Lower Miocene. Lower Harrison formation, approximately 120 feet above the Brule-lower Harrison contact. S.E.¼. Sec. 22. T. 20N. R. 60W. Goshen County, Wyoming.

Specific characters. The smallest known *Nanotragulus.* Molars, especially M^1, quadrangular in outline. P^3 with internal cusp present but very small. Parastyle of M^3 does not overlap M^2 as much as in *N. loomisi.* Also, the bulla is smaller and more compressed than in that species. Facial crest reduced. Orbit almost closed behind. I_3 larger than other incisors. P_2 and P_3 closely appressed. (See Figures 12–13 and Plates 40–41).

Description and discussion. The basicranial region is proportionately long. The basioccipital is broad and the tympanic bulla is smaller and more transversely compressed than in *N. loomisi.* The paroccipital process is short and compressed. At its base it is firmly braced against the bulla immediately behind which the hyoid process is deeply embedded. The whole basicranial region is very similar to that of *Tragulus* except that in the latter there is a pterygoid process on the anterior of the bulla and the petrosal bone does not appear on the surface between the bulla and the basioccipital. The external auditory meatus is incomplete and projects upward and backward. A short distance above there is a large squamosal foramen. The occipital condyles are low, broad and rather distantly separated,— more so above than below. The supraoccipital is high, narrow and transversely convex. The mastoid portion of the periotic extends far up on the side of the skull and is amost in contact with the parietal. The lambdoid and sagittal crests are weakly developed. The cranium is arched and is somewhat expanded. There is a slight postorbital constriction. The postorbital bar

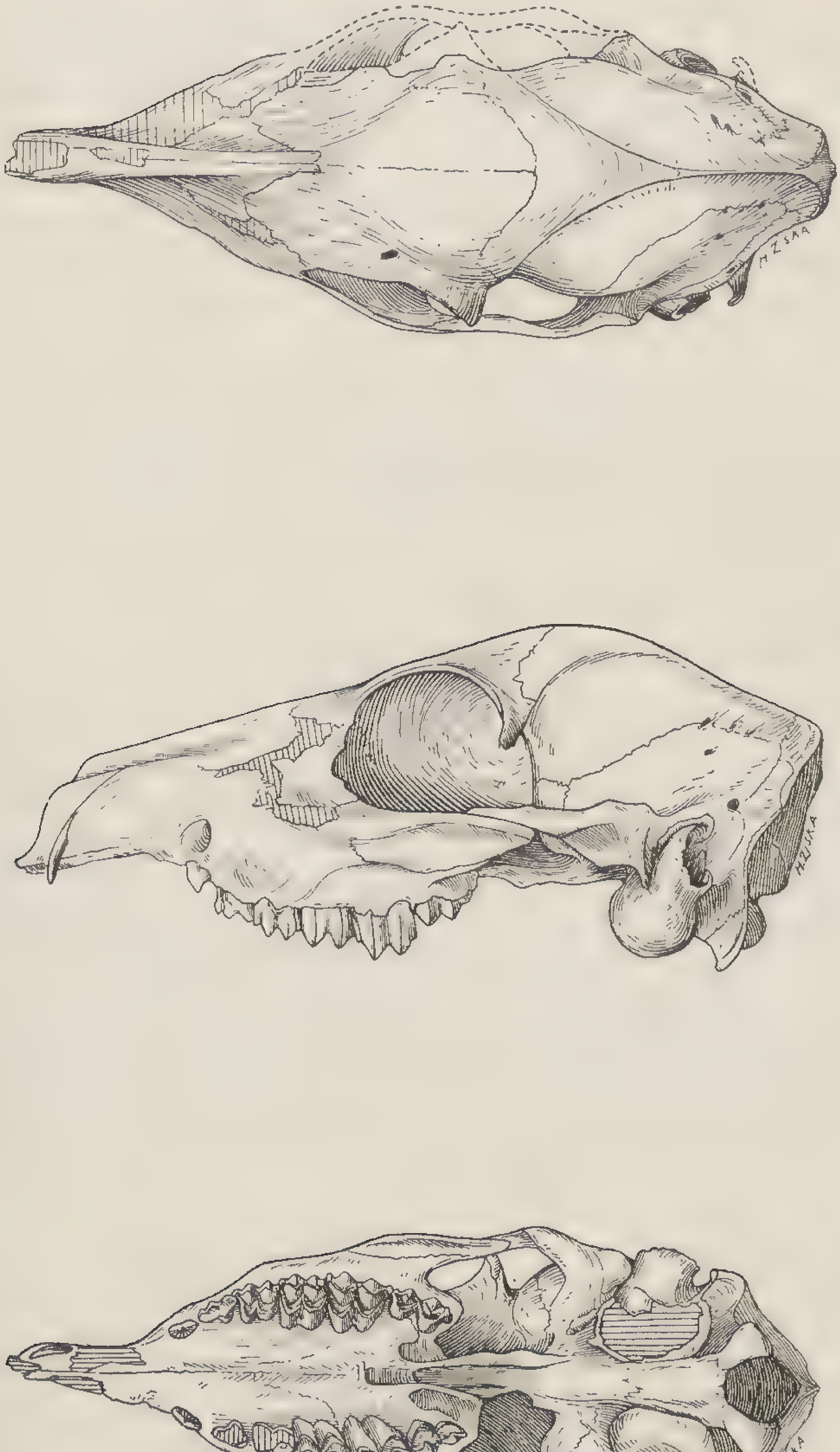

FIG. 12.—*Nanotragulus intermedius.* Type. Dorsal, lateral and palatal views of the skull. Natural size. Drawn by Helen Ziska.

is almost complete. The malar is large and elongated. On its external surface there is a prominent ridge which extends forward and grades into the short and low facial crest of the maxilla. The lacrimal is large and occupies a considerable portion of the face immediately in front of the orbit. The facial region is short, deep and very narrow. The infraorbital foramen is above the second molar. It occupies a slightly more posterior position in a young individual. The palate is narrow and the internal nares are rather far forward (opposite the posterior of M^2).

There is an internal cingule on each of the upper molars of the type specimen. The cingule is absent on the teeth of the adult paratype skull. Since in almost all of their other characters these two specimens are so much alike the presence or absence of a cingule may be regarded as an individual variation. The canine is small and slightly compressed transversely. P^1 is minute and is situated about midway between the canine and P^2. P^2 is set close to P^3. It is two-rooted and has a single-cusped crown which is oval in outline. P^3 has the general form of P^4 although with the internal cusp much reduced. In premolar development, therefore, *N. intermedius* forms an ideal intermediate stage between *N. loomisi* and *Hypertragulus*. DP^3 has three external and one postero-internal cusp. DP^4 is completely molariform.

The mandible is long and slender. Posteriorly it is deep and expanded. The mandibular condyle is large, flattened and considerably elevated above the tooth-row. The coronoid is high, slender and recurved. The symphysis is fairly short and narrow. There is a short diastema between the canine and P_1. The canine is completely incisiform and is of the same size as I_3. I_1 and I_2 are larger. P_1 is caniniform. There is no diastema between P_2 and P_3. DP_4 is of the typical artiodactyl three-crested pattern. DP_3 has the same general pattern except that the anterior crest is less developed. There is a minute external cingule on each of the lower molars.

Previously two species have been referred to the genus *Nanotragulus* and the above description adds a third. The type *N. loomisi* from the lower Harrison of eastern Wyoming was described by Professor Lull (1922, pp. 116–119) who immediately recognized its hypertragulid characters and placed it in the family Hypertragulidae but stated that, "it is not clearly derivable from any known Oligocene form except possibly *Hypisodus*" (p. 119). Dr. Matthew (1926, p. 3) assigned a fragmentary skull and jaws in the "lower Rosebud" collection at the American Museum to Professor Lull's genus and species and pointed out its close affinity to *Hypertragulus calcaratus* from the middle Oligocene of South Dakota. He also referred *H. ordinatus* Matthew (only the jaws of this species are known) to *Nanotragulus*. Dr. Loomis (1933) has described a fragmentary skeleton, also from the "lower Rosebud," which he regards as *N. loomisi*. In his discussion of the *Hypertragulus-Nanotragulus* affinity he considered the former "to be the immediate predecessor of *Nanotragulus*."

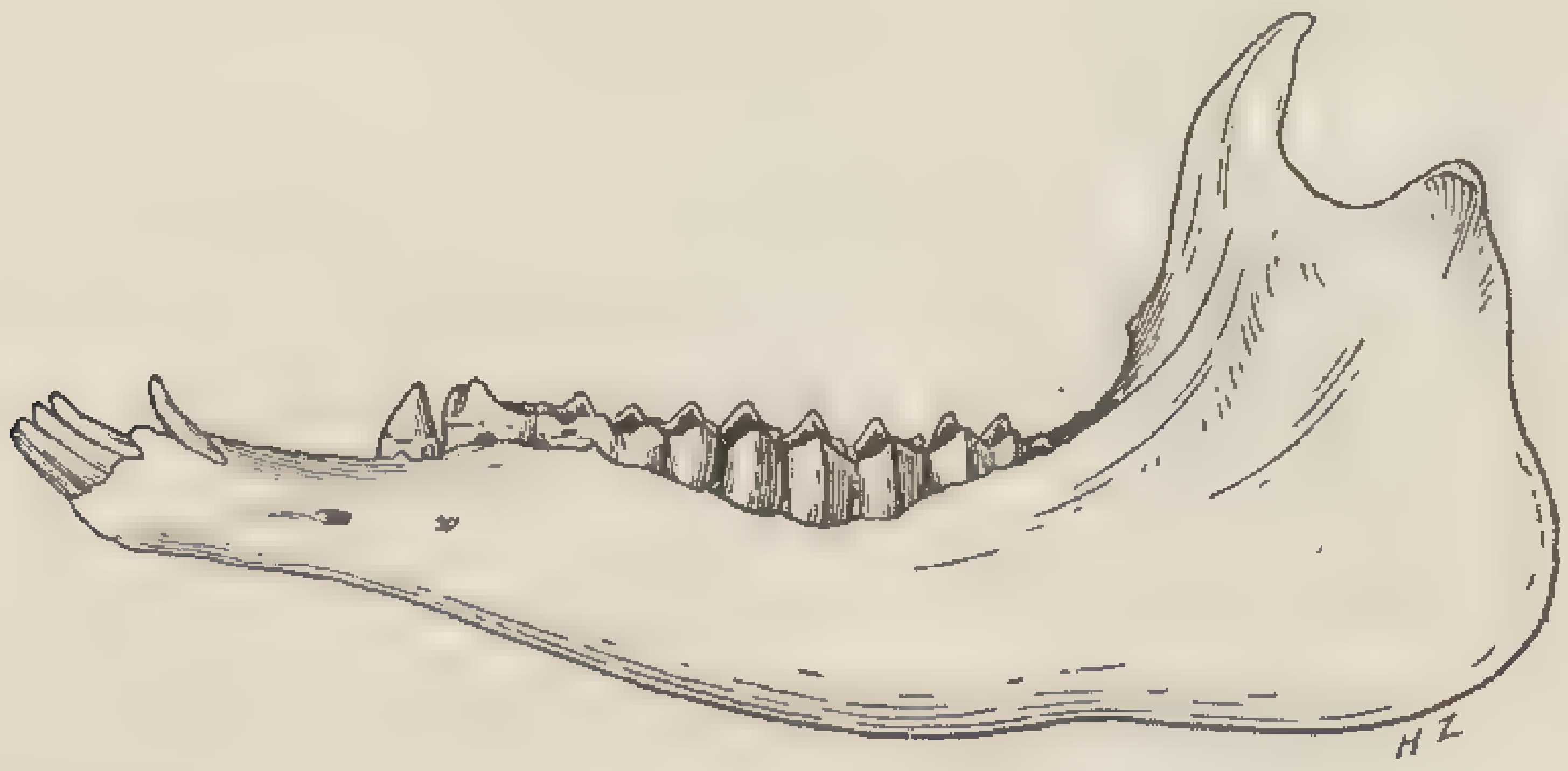

FIG. 13. *Nanotragulus intermedius*. Type. Lateral view of the left lower jaw. Natural size. Drawn by Helen Ziska.

On the basis of its rather small and compressed bullae, its incipient internal cusp on P^3 and its small size, *N. intermedius* is the most primitive of the described *Nanotragulus* species. Structurally it forms an ideal predecessor for *N. loomisi* and in the above characters it is intermediate between this species and *Hypertragulus*. *N. ordinatus* (Matthew) is the largest species and could be the lineal descendant of *N. loomisi*. Of the known species of *Hypertragulus*, *H. minutus* Lull from the upper Oligocene (upper John Day) of Oregon, is nearest to *Nanotragulus* and may, tentatively, be considered directly ancestral to that genus.

Measurements

	mm.
Condylo-basal length	72.0
Greatest length of the skull	80.0
Greatest breadth across squamosals on cranium	23.5
Interorbital breadth across frontals	21.5
Distance from anterior rim of orbit to front of pmx.	34.5
Distance from anterior rim of orbit to supraoccipital	49.0
Greatest width of condyles	14.0
Distance from ventral portion of exocc. to top of supraocc.	25.5

Breadth of muzzle at entrance of infraorbital foramina	9.5
Distance from anterior of canine to anterior of P^2	14.0
Length of P^2–M^3	25.5
Length of M^1–M^3	16.0
Distance from posterior of I_1 alveolus to mandibular condyle	58.0
Greatest length of mandible	61.0
Length of the symphysis	12.0
Depth of jaw under coronoid	29.5
Width of condyle	6.5
Length of diastema between P_1 and P_2	7.5
Distance from P_1 to P_4	20.8
Distance from M_1 to M_3	28.0

HYPISODUS ALACER Troxell

Material. A left inferior third molar with a fragment of the mandible, M. C. Z. No. 2,873. Collected by Erich M. Schlaikjer, 1932.

Horizon and locality. Middle Oligocene. Brule formation, upper part of the middle oreodont zone. Harvard Fossil Reserve. Goshen County, Wyoming.

Discussion. This specimen is slightly larger than the M_3 of *H. alacer* and differs from that species principally in the more reduced heel and in the more transversely compressed character of the metacone-metaconule crest. The discovery of more complete material may prove this form specifically distinct from *H. alacer.* For the present, however, it may be referred to that species.

LEPTOMERYX EVANSI Leidy

Material. A fragmentary skull and jaws, M. C. Z. No. 2,926. Collected by Erich M. Schlaikjer, 1932.

Horizon and locality. Lower Oligocene. Chadron formation. N.W.¼. Sec. 36. T. 24N. R. 63W. Goshen County, Wyoming.

Discussion. The occurrence of this species in the upper level of the Chadron in Goshen Hole is of no particular significance. It has a considerable vertical range for it occurs up through the oreodont beds of the Brule formation, and it is found in these deposits throughout the Great Plains Region.

LEPTOTRAGULUS ULTIMUS sp. nov.

Type. A superior left third molar, M. C. Z. No. 2,872. Collected by Erich M. Schlaikjer, 1932.

Horizon and locality. Lower Oligocene. Chadron formation. N.E.¼. Sec. 19. T. 23N. R. 61W. Goshen County, Wyoming.

Specific characters. The largest known *Leptotragulus.* Very heavy internal cingulum. Anterior cingulum moderately developed and postero-internal cingulum absent. (See Plate 41).

Discussion. Leptotragulus proavus, the type of the genus, was described by Professors Scott and Osborn (1887 and 1890) from the Uinta formation of the Eocene. It was based on a fragmentary lower jaw with several teeth. In 1919 Mr. O. A. Peterson described (pp. 93–97) and figured, from the same formation, several upper and lower dentitions which he rightfully referred to this species. In the same publication he described a new species, also from the Uinta, to which he gave the name *L. medius* and which he distinguished from *L. proavus* principally on the basis of the larger styles and absence of cingula on the superior molars. A third species "*L.*" *profectus* was described by Dr. Matthew (1903, p. 224) from the Pipestone Springs bed (Chadron) of Montana. The type is a fragmentary lower jaw with P_2–M_1. As shown by Dr. Matthew, this species is a large and very cameloid form. Its inclusion in *Leptotragulus* was questioned by Dr. Matthew himself (1909, p. 104) and, as suggested by Mr. Peterson (1919, p. 97), perhaps should not be included in that genus.

The molar tooth of *L. ultimus* possesses every advanced character which would be expected in an Oligocene representative of this genus. These characters showing advanced changes over the upper Eocene forms are as follows: the large size, the proportionately broad paracone-protocone dimension and the heavy internal cingulum. *L. proavus* may be considered directly ancestral to this species.

Measurements

	mm.
Greatest antero-posterior dimension of M^3	8.0
Width of M^3 across paracone-protocone	11.0
Width of M^3 across metacone-metaconule	8.5

CONCLUSIONS

1. The Chadron formation rests with conformity and disconformity on the Yoder formation and is overlain with disconformity by the Brule. Lithologically, and in so far as the fauna is known, is it indistinguishable from the deposits of this formation in Nebraska and South Dakota.

2. The Brule is fully represented in the area. The lower channel sandstone member is probably comparable to the *Metamynodon* sandstone in other areas. The rich fossil deposit at the Harvard Fossil Reserve is unquestionably the correlate of the upper nodular layer in the South Dakota Big Bandlands.

3. Most of the lower Miocene in the area is lower Harrison in age and is typically four hundred feet in thickness. The upper three hundred feet of the seven hundred feet of the Miocene in Six Mile, Deer and Cherry Creek vicinity is probably upper Harrison.

4. The "Gering formation" represents only a lower channel phase of the lower Harrison and should not be regarded as a distinct formation.

5. The Monroe Creek beds, the lower Rosebud and the lower Harrison are synchronous deposits. The fauna and lithology are variable only in so far as they were governed by local environmental and depositional conditions.

6. The Goshen Hole Area has been subjected to at least five diastrophic movements since the late Cretaceous. These took place at the close of the Fox Hills, between the Cretaceous and early Oligocene, at the end of the Chadron, at the end of the Brule and since the end of the Miocene.

7. In the large collection of Oligocene and early Miocene vertebrates, two genera and thirteen species herein described are new. They are as follows: *Palaeolagus hypsodus, Hypolagus primitivus, Nothocyon leptodus, Mesocyon hortulirosae, Pediohippus antiquus* (a new genus), *Parahippus wyomingensis, Hypohippus avus, Archaeotherium palustris, Dinohyus minimus, Leptauchenia minora, Miotylopus bathyganthus* (a new genus), *Nanotragulus intermedius*, and *Leptotragulus ultimus*.

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1921. Two new forms of *Agriochoerus*. Amer. Jour. Sci., **3**, pp. 111–119, 4 text figures.

1921. *Leptauchenia* Leidy and *Cyclopidius* (*Pithecistes*) Cope, descriptions of new and little known forms in the Marsh collection. Amer. Jour. Sci., **1**, pp. 405–419, 6 text figures.

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1931. The osteology of *Eporeodon socialis* Marsh. Bull. Peabody Mus. Nat. Hist., **2**, pp. 1–43, 23 text figures.

TROXELL, E. L.

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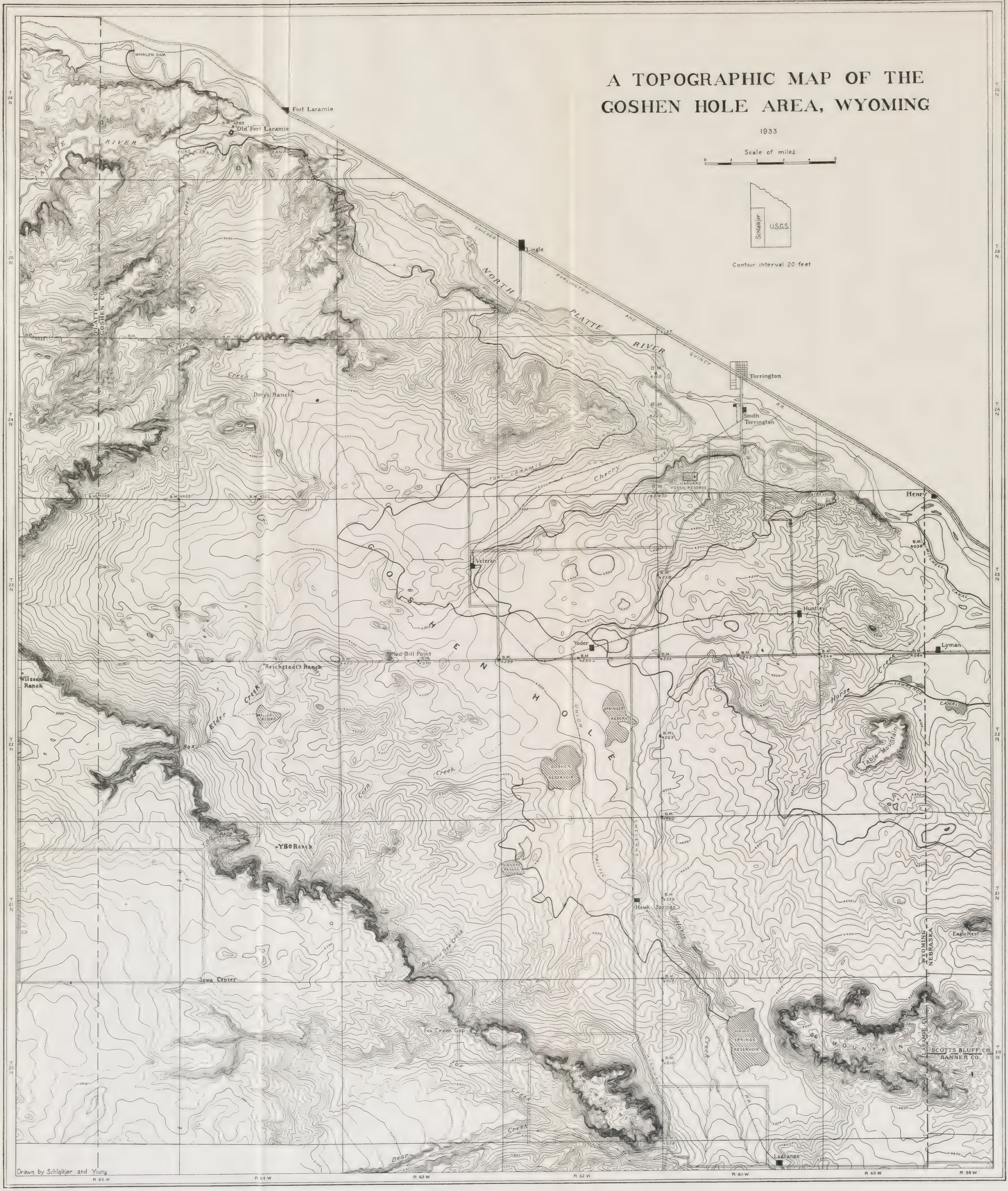
1920. Entelodonts in the Marsh collection. Part I. Morphology and taxonomy. Amer. Jour. Sci., **50**, pp. 243–255, pl. 3.

1920. Entelodonts in the Marsh collection. Part II. The genus *Archaeotherium*. Amer. Jour. Sci., **50**, pp. 361–386, 12 text figures.

1920. Entelodonts in the Marsh collection. Part III. The larger genera and species. Amer. Jour. Sci., **50**, pp. 431–445, 20 text figures.

EXPLANATION OF PLATES

PLATE 1



A TOPOGRAPHIC MAP OF THE GOSHEN HOLE AREA, WYOMING

1933

Scale of miles

Contour interval 20 feet

Drawn by Schlaikjer and Young

0 1 2 3 4 5
Schlaikjer
U.S.G.S.
Whalen Dam
Fort Laramie
"Old" Fort Laramie
Laramie River
Fort Laramie Canal
Deer Creek
Lingle
North Platte River
Chicago Burlington and Quincy R.R.
Torrington
South Torrington
Cherry Creek
Doty's Ranch
Platte Co.
Goshen Co.
Harvard Fossil Reserve
Henry
Veteran
Goshen Hole
Huntley
Yoder
Lyman
Red Bill Point
Reichstadt's Ranch
Wilson's Ranch
Elder Creek
Box Elder Creek
Springer Reservoir
Goshen Reservoir
Union Pacific
Horse Creek
Lawrence Canal
Table Mountain
Corn Creek
YBO Ranch
Hawk Springs
Cheyenne
Big Lone Tree Creek
Iowa Center
Fox Creek Gap
Fox Creek
Bear Creek
Bear Creek Mountain
Hawk Springs Reservoir
Wildcat Mountain
Eagle Nest
Wyoming
Nebraska
Laramie Co.
Scotts Bluff Co.
Banner Co.
Lagrange
T 26 N
T 25 N
T 24 N
T 23 N
T 22 N
T 21 N
T 20 N
R 65 W
R 64 W
R 63 W
R 62 W
R 61 W
R 60 W
R 58 W

PLATE 2

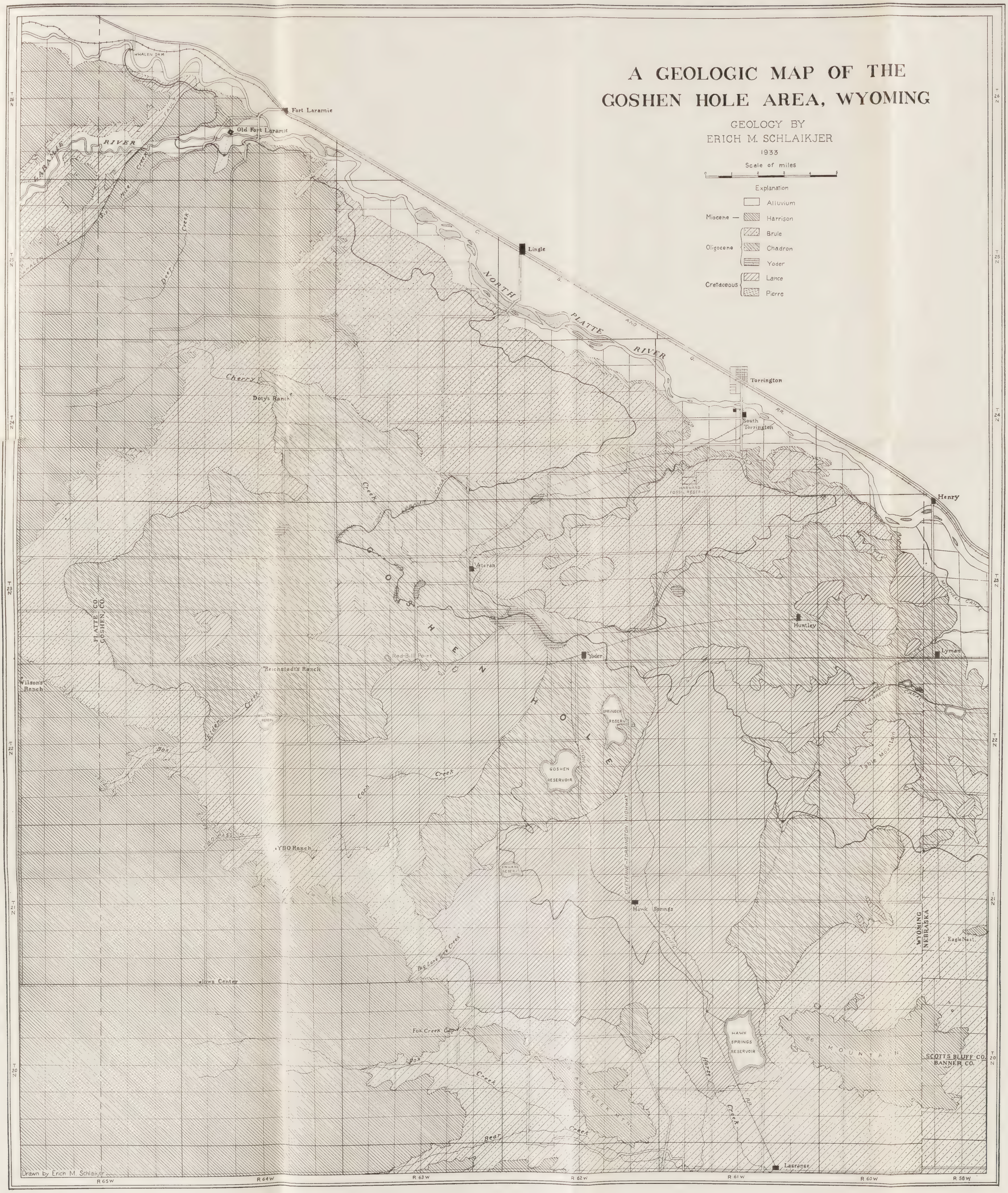

A GEOLOGIC MAP OF THE GOSHEN HOLE AREA, WYOMING
GEOLOGY BY
ERICH M. SCHLAIKJER
1933
Scale of miles
0
1
2
3
4
5
Explanation
Alluvium
Miocene — Harrison
Oligocene
Brule
Chadron
Yoder
Cretaceous
Lance
Pierre
WHALEN DAM
Fort Laramie
Old Fort Laramie
LARAMIE RIVER
FAULT
Six Mile Creek
Deer Creek
WHALEN
Lingle
NORTH PLATTE RIVER
C. B. AND Q. RR.
Torrington
South Torrington
HARVARD FOSSIL RESERVE
Henry
Cherry Creek
Doty's Ranch
GOSHEN HOLE
Veteran
MITCHELL CANAL
Huntley
Lyman
LAWRENCE CANAL
Table Mountain
Yoder
Red-Bill Point
PLATTE CO.
GOSHEN CO.
Wilson's Ranch
Reichstadt's Ranch
Elder Creek
MILLER RESERV.
Box
SPRINGER RESERV.
GOSHEN RESERVOIR
UNION
Corn Creek
YBO PASS
YBO Ranch
SINNARD RESERV.
CHEYENNE-TORRINGTON HIGHWAY
Hawk Springs
PACIFIC
Big Lone Tree Creek
WYOMING
NEBRASKA
Eagle Nest.
Iowa Center
Fox Creek Gap
Fox Creek
HAWK SPRINGS RESERVOIR
Horse Creek
RR.
66 MOUNTAIN
SCOTTS BLUFF CO.
BANNER CO.
Bear Creek
Lagrange
Drawn by Erich M. Schlaikjer
T 26 N
T 25 N
T 24 N
T 23 N
T 22 N
T 21 N
T 20 N
R 65 W
R 64 W
R 63 W
R 62 W
R 61 W
R 60 W
R 58 W

PLATE 3

PLATE 3

FIG. 1. Red-Bill Point showing upper Chadron channel sandstone.

FIG. 2. Volcanic ash in the Brule formation at the east side of Table Mountain.

1

2

PLATE 4

PLATE 4

FIG. 1. Looking eastward. Harvard Fossil Reserve. Bone layer immediately below laboratory building.

FIG. 2. Collecting a large block of fossils in the Harvard Fossil Reserve.

1

2

PLATE 5

PLATE 5

Fig. 1. Dip in the Brule formation at Fox Creek Pass.

Fig. 2. Brule-lower Harrison channel deposit resting on Brule clay. Northeast of Wilson's Ranch.

1

2

PLATE 6

PLATE 6

Fig. 1. Brule-lower Harrison channel deposit resting on Brule clay. Sec. 36. T. 25N. R. 63W.

Fig. 2. Eagle Rock at Fox Creek Pass showing the lower Harrison formation.

1

2

PLATE 7

PLATE 7

Looking southeast at Sixty Six Mountain showing the Brule-lower Harrison contact and the gentle dip southeastward.

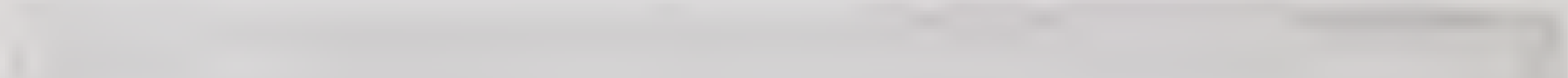
PLATE 8

PLATE 8

FIG. 1. East view down the North Platte River valley overlooking the upper lower Harrison beds which have been faulted down below the upper Brule (immediate foreground).

FIG. 2. Whalen Fault showing the Brule clay above the lower Harrison.

1



2

PLATE 9

PLATE 9

Fig. 1. The Whalen Fault, same locality as in Plate 8.

Fig. 2. Close view of the fault-plane.

Photographs, Plates 3–9, by Erich M. Schlaikjer

Brule
L. Miocene

1

2

PLATE 10

PLATE 10

Testudo peragrans Hay

Referred specimen. Skull and carapace. One-fourth natural size.

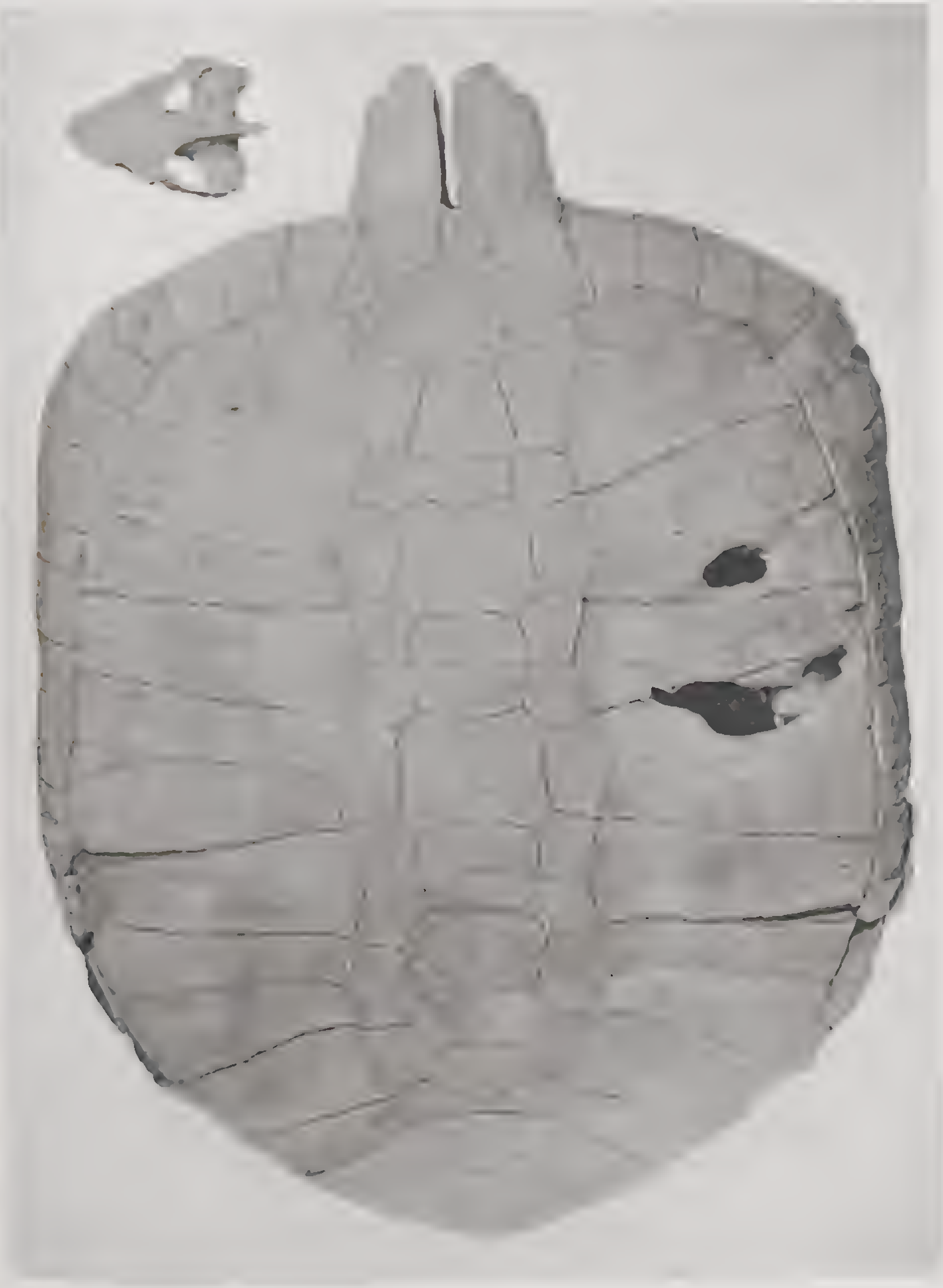


PLATE 11

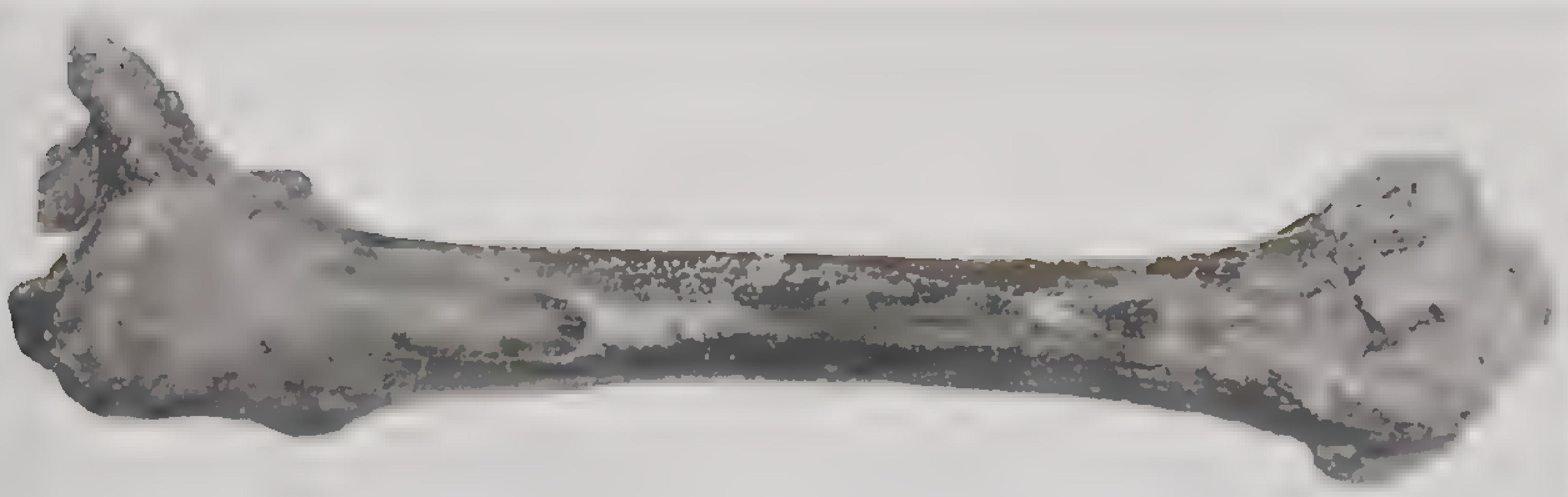
PLATE 11

MESOCYON HORTULIROSAE Schlaikjer

Referred specimen. Right hind limb and right humerus. Approximately three-fourths natural size.

Photographs, Plates 10–11, by W. L. Hallowell.

1



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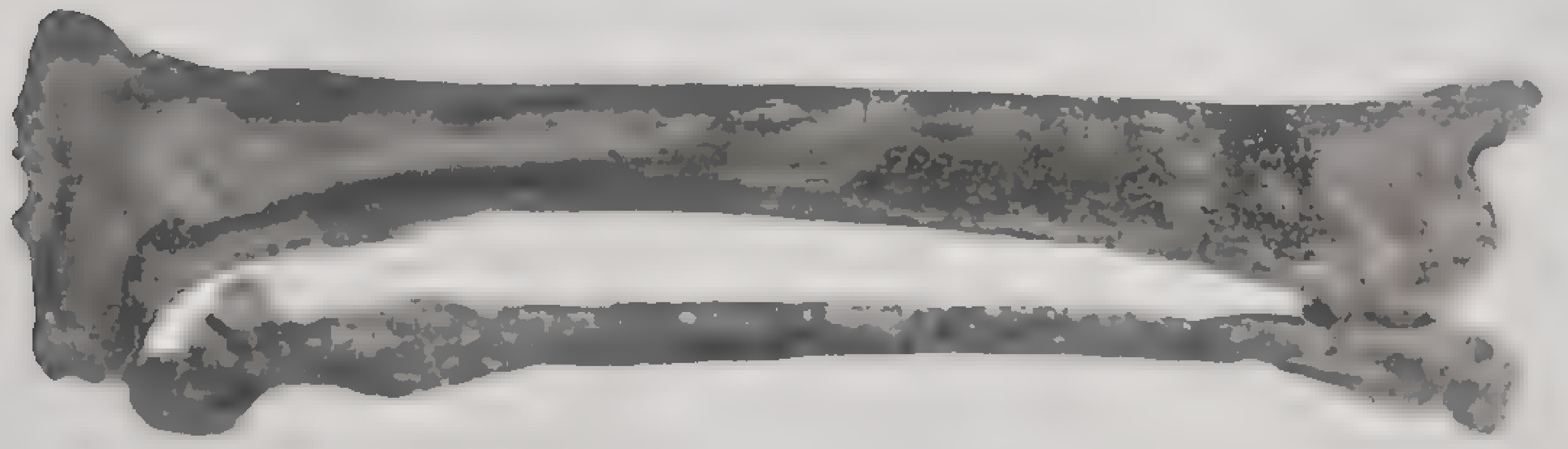

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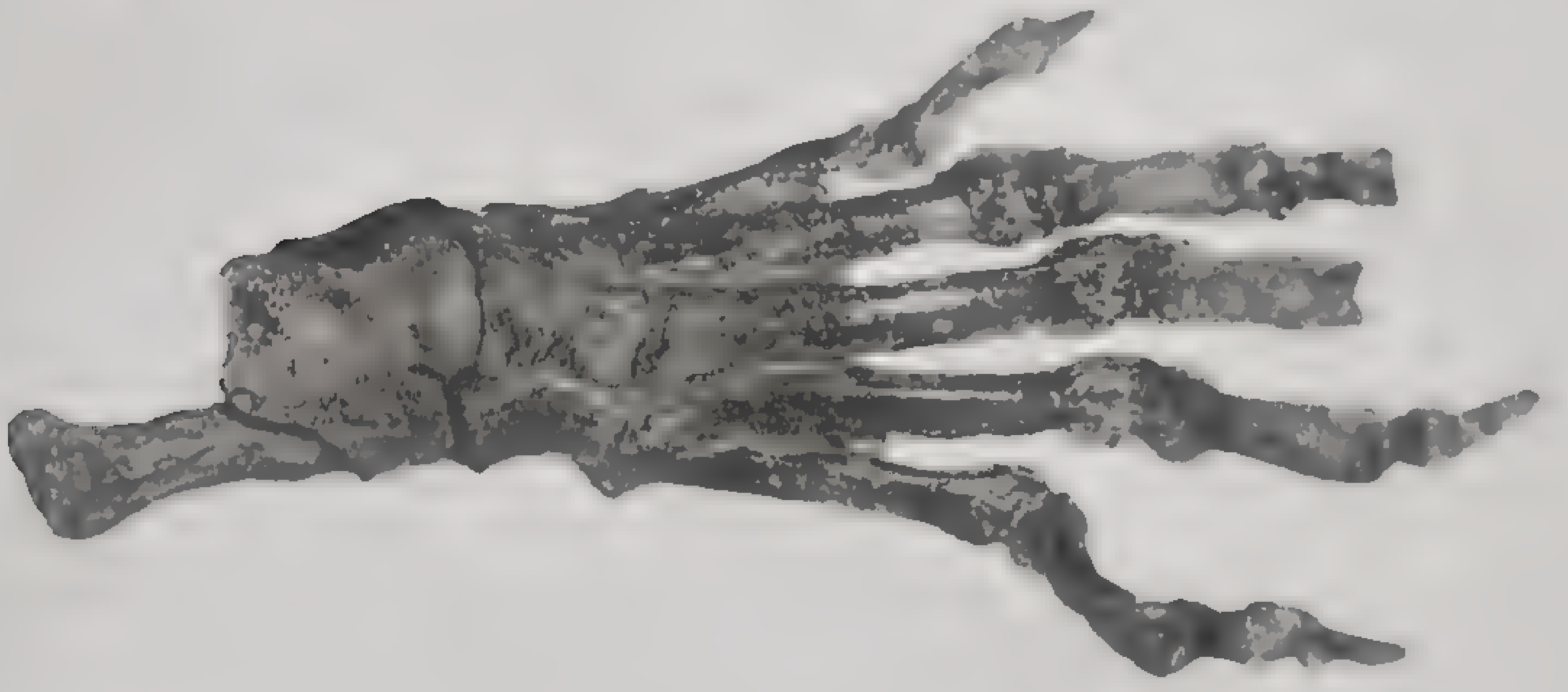

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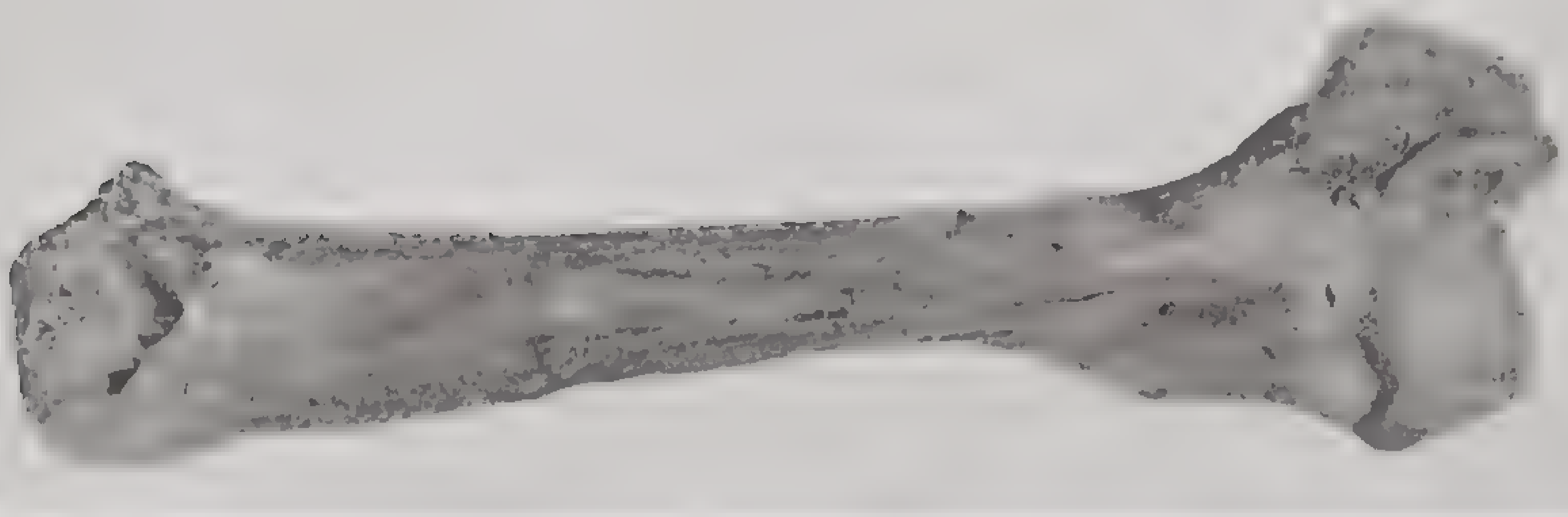


PLATE 12

PLATE 12

Fig. 1. *Parahippus pristinus* Osborn. Type. Palatal view of left P^1–M^3.

Fig. 2. *Pediohippus brachystylus* (Osborn). Type. Palatal view of left P^1–M^3.

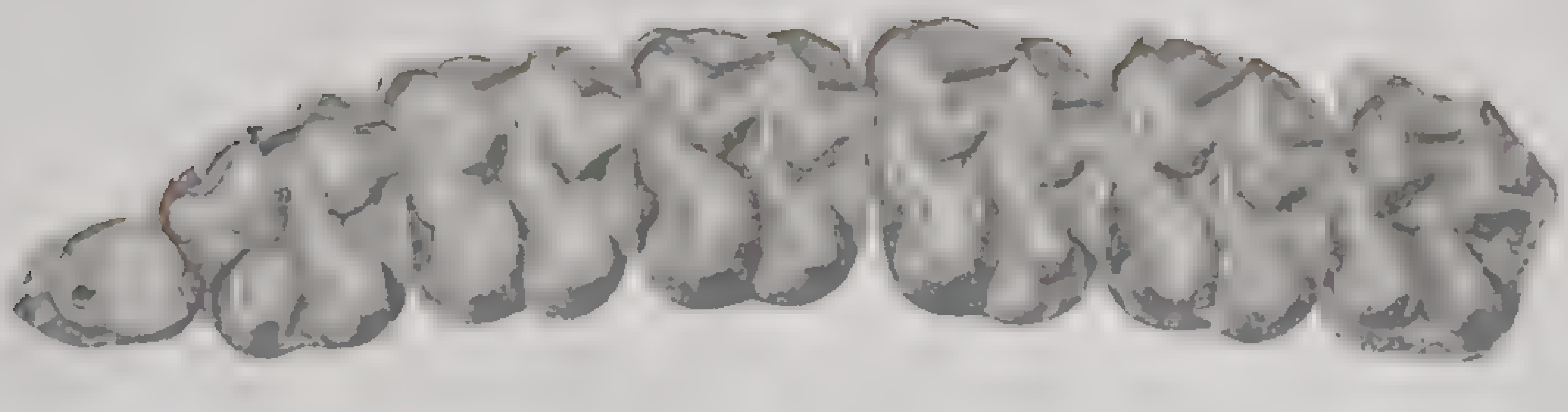
Fig. 3. *Pediohippus antiquus* Schlaikjer. Genoholotype. Palatal view of left P^2–M^3.

Fig. 4. *Pediohippus trigonostylus* (Osborn). Referred specimen. Palatal view of left P^2–M^3.

All Figures natural size.

Drawings by Gladys De Grout Schlaikjer.

1



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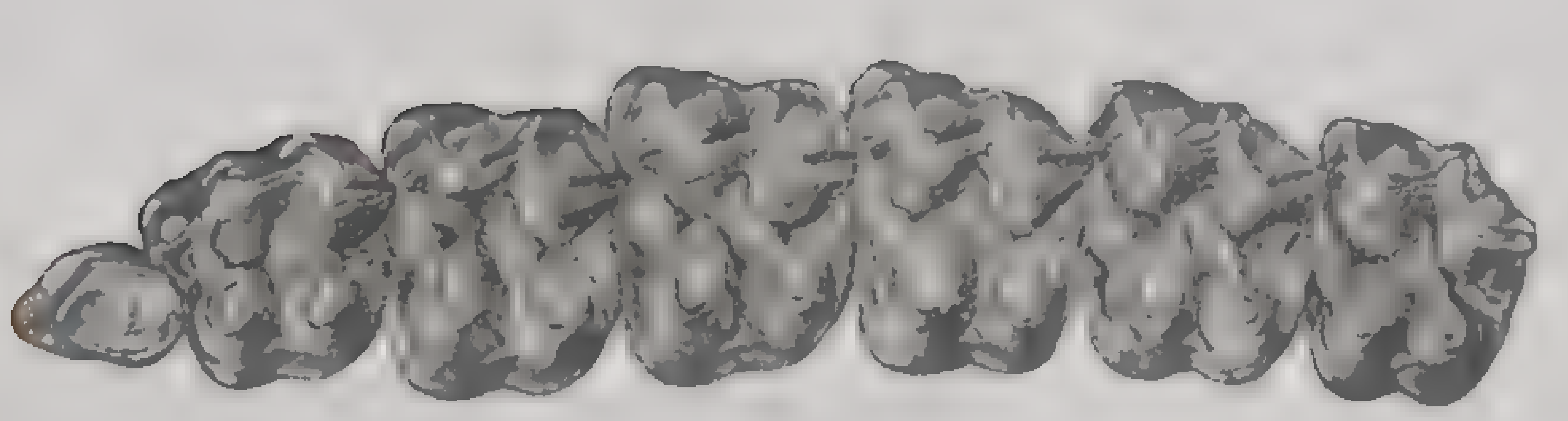

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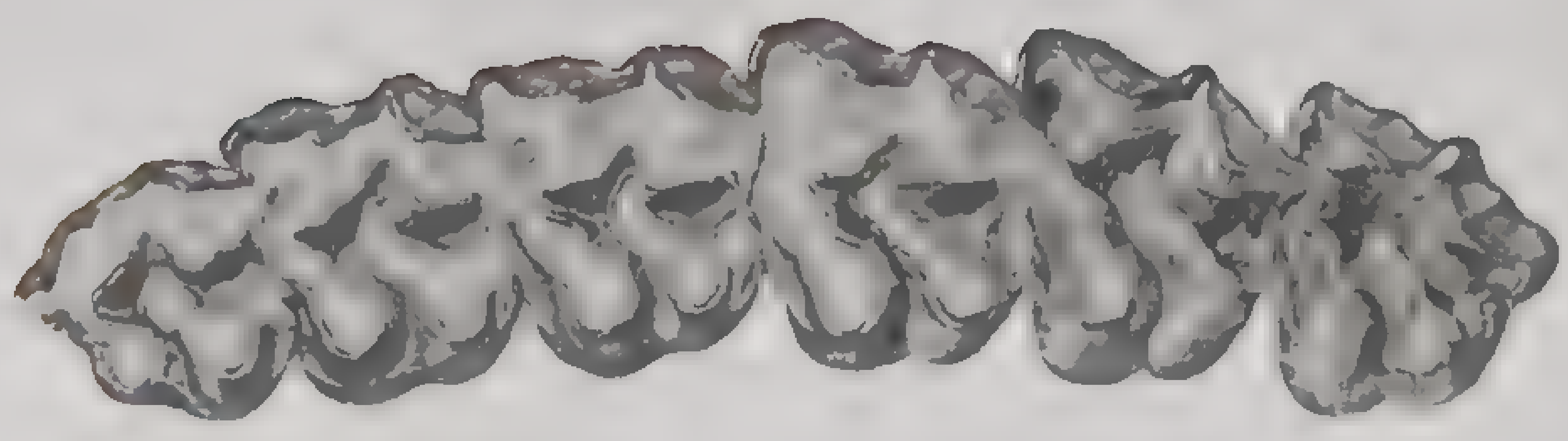

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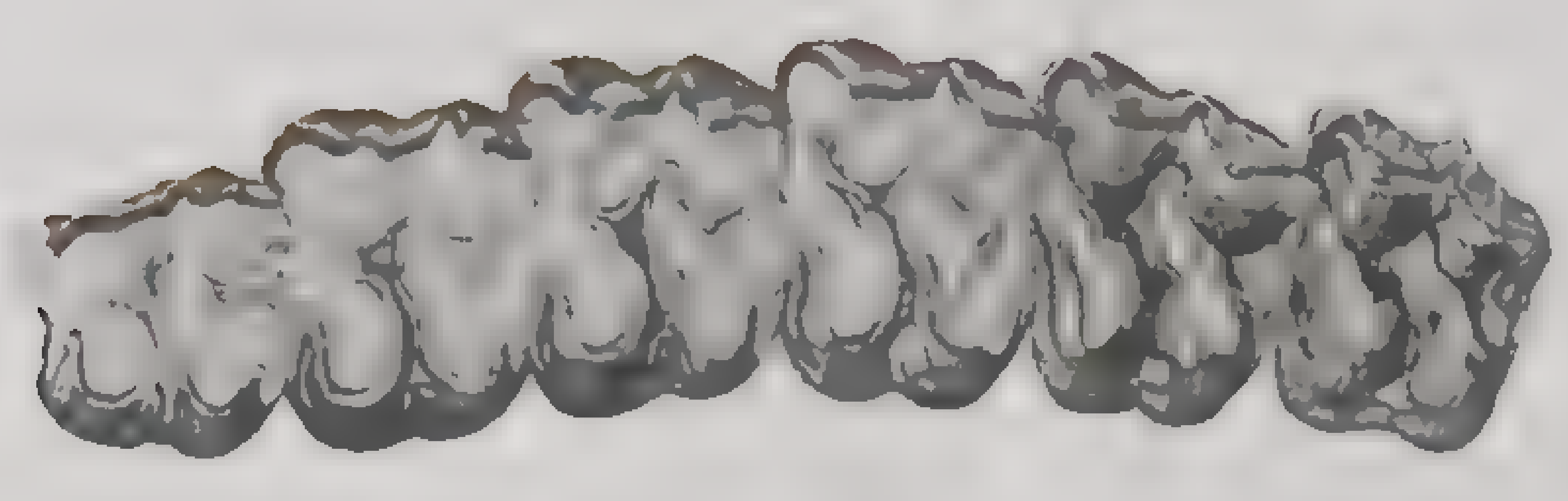


PLATE 13

PLATE 13

Mesohippus barbouri Schlaikjer

Referred specimen. Palatal view of the skull. Natural size.

Photograph by W. L. Hallowell.

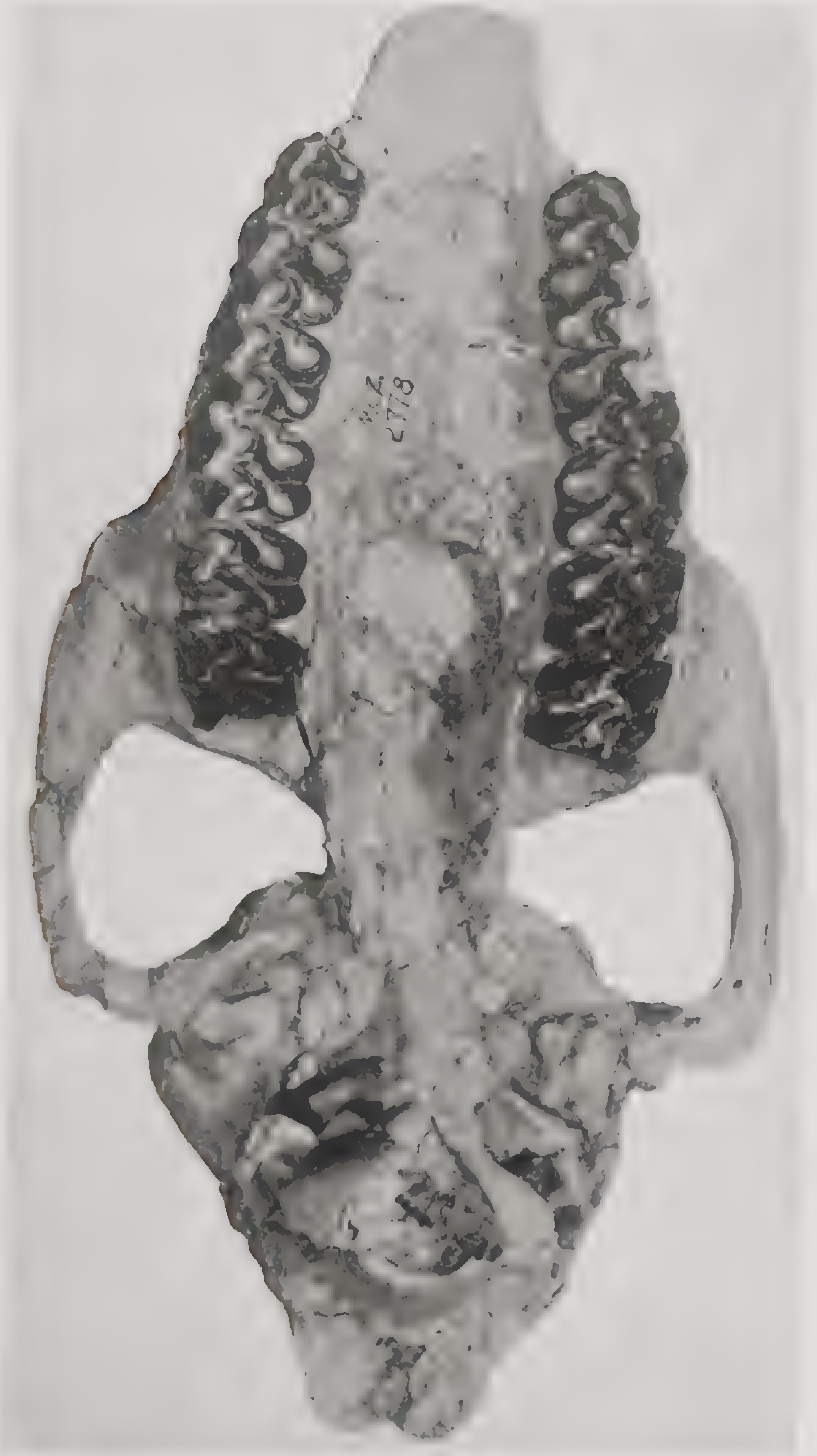


PLATE **14**

PLATE 14

Parahippus wyomingensis Schlaikjer

Type. Superior and lateral view of the skull. One-third natural size.

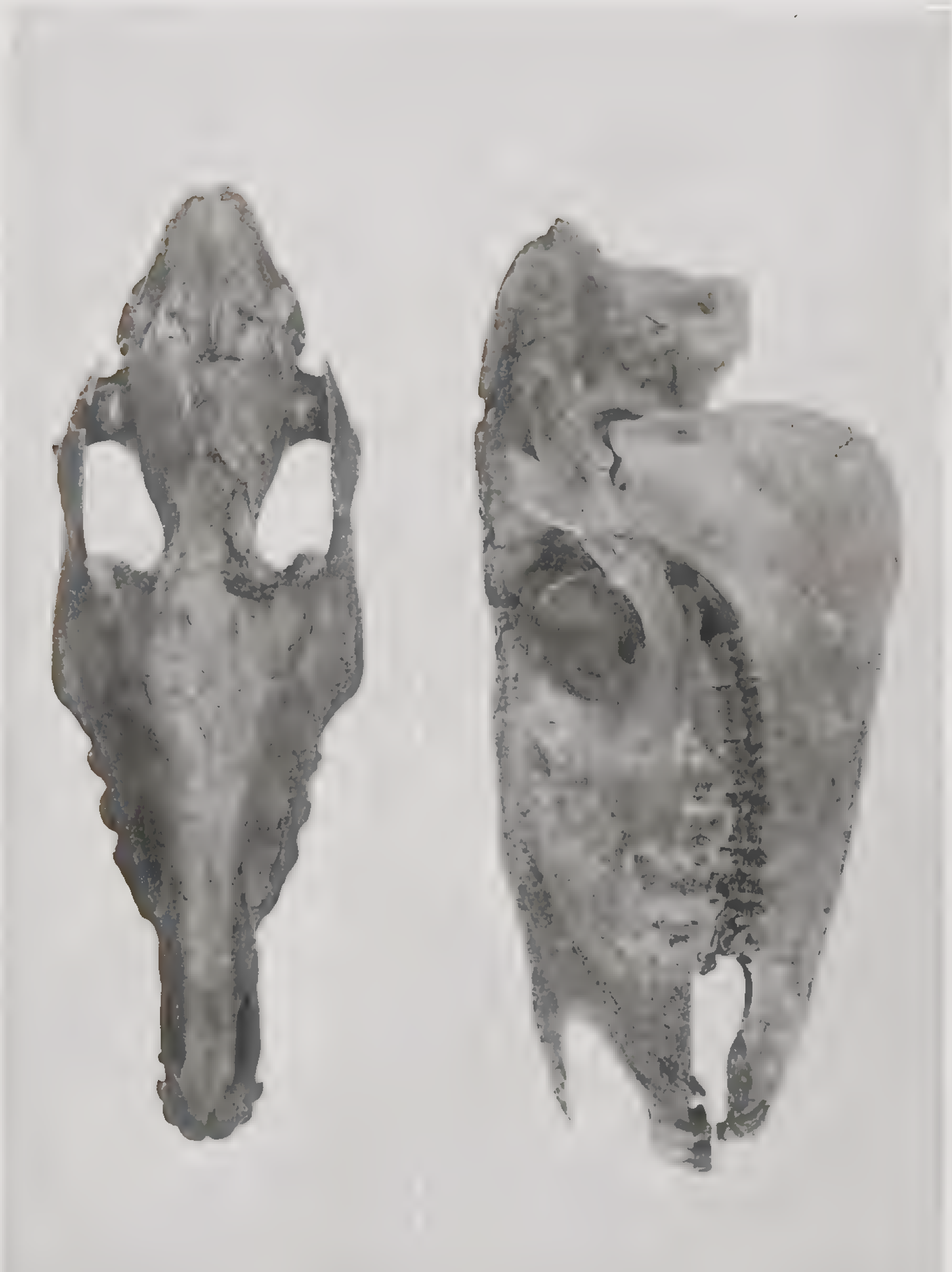


PLATE 15

PLATE 15

PARAHIPPUS WYOMINGENSIS Schlaikjer

Type. Palatal views of skull and jaws. One-third natural size.

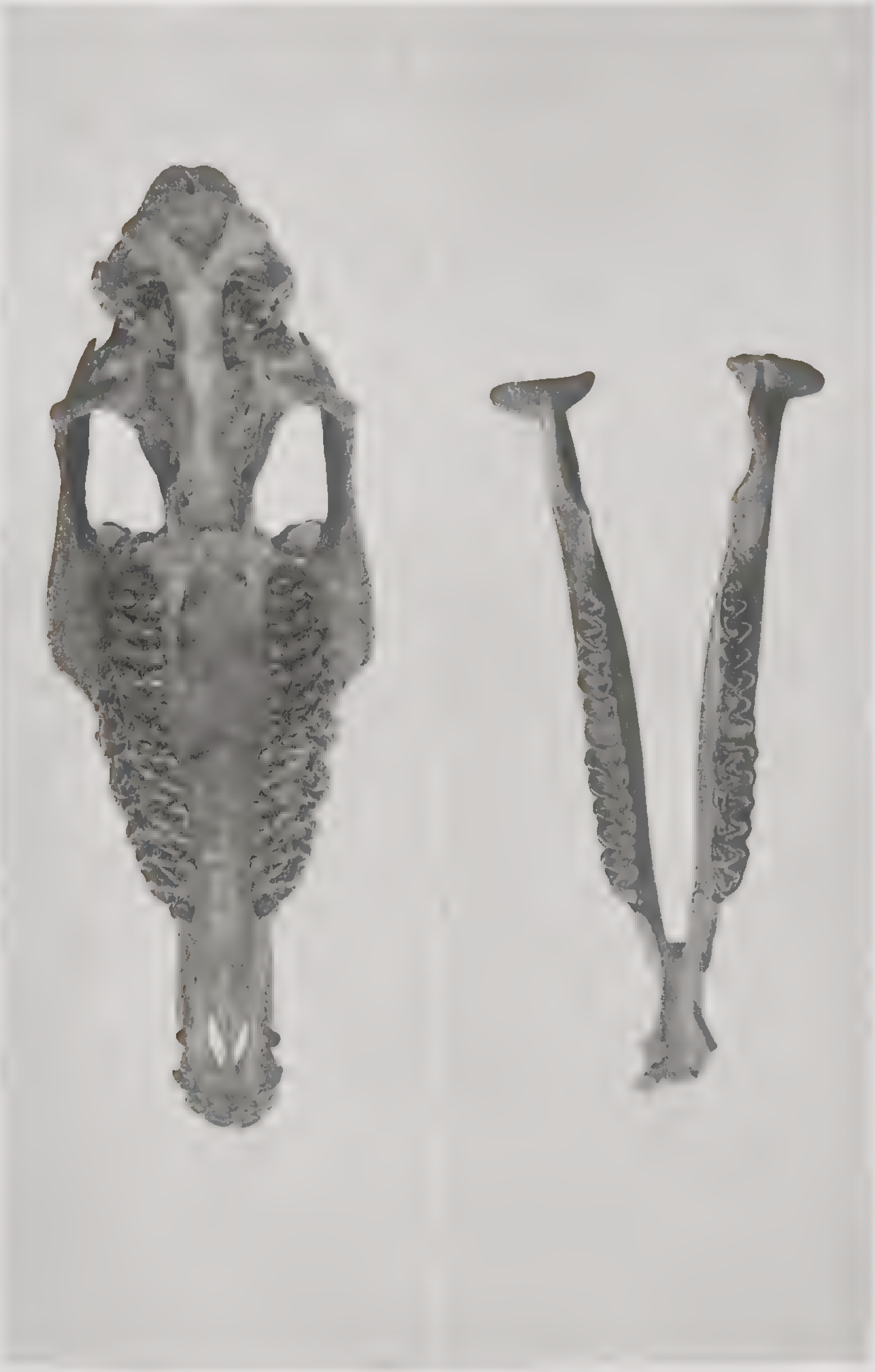


PLATE 16

PLATE 16

Parahippus wyomingensis Schlaikjer

Type. External and anterior views of right hind foot. One-third natural size.

Photographs, Plates 14–16, by George Nelson.

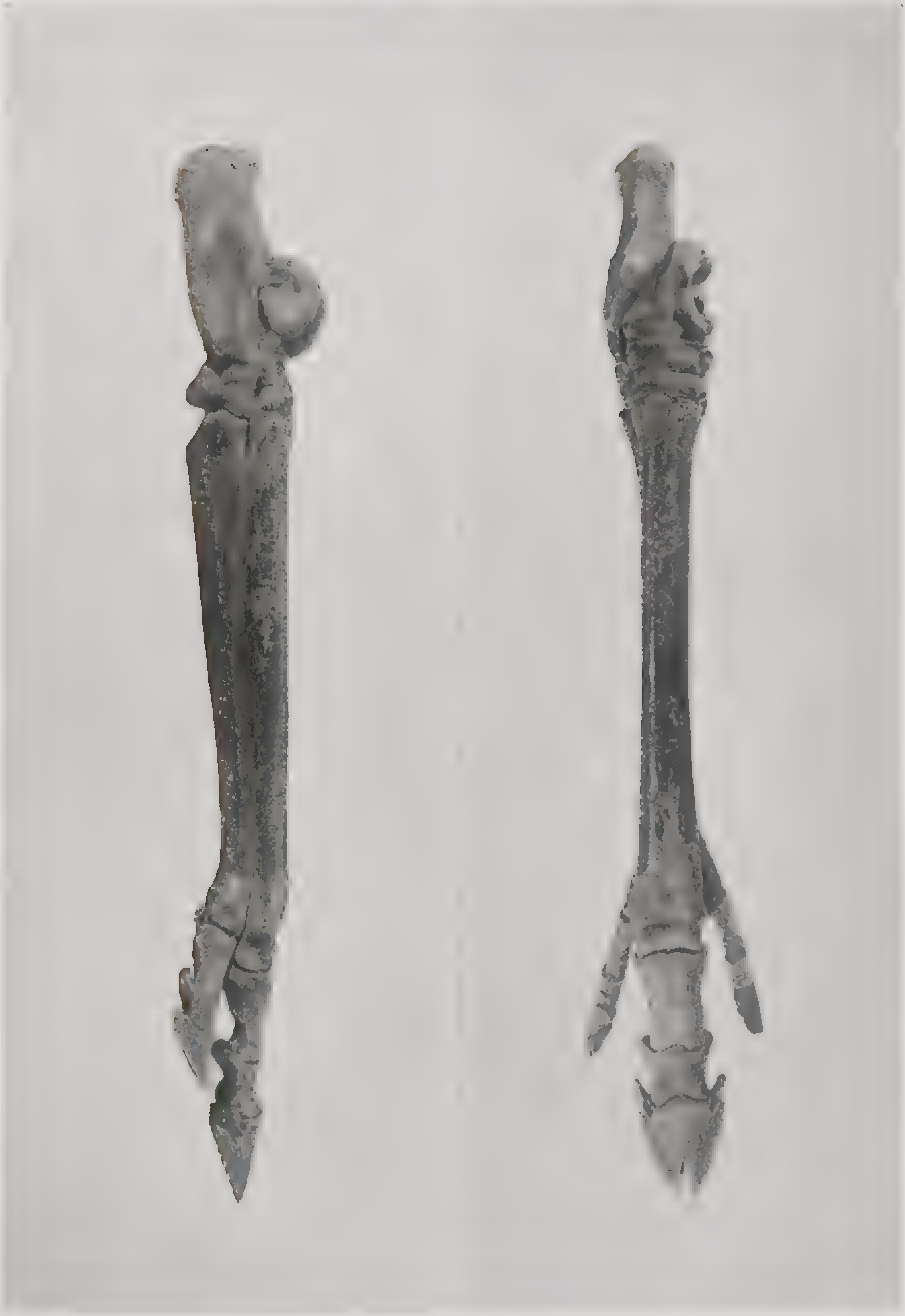


PLATE 17

PLATE 17

Hypohippus avus Schlaikjer

Type. Lateral view of skull. Two-thirds natural size.

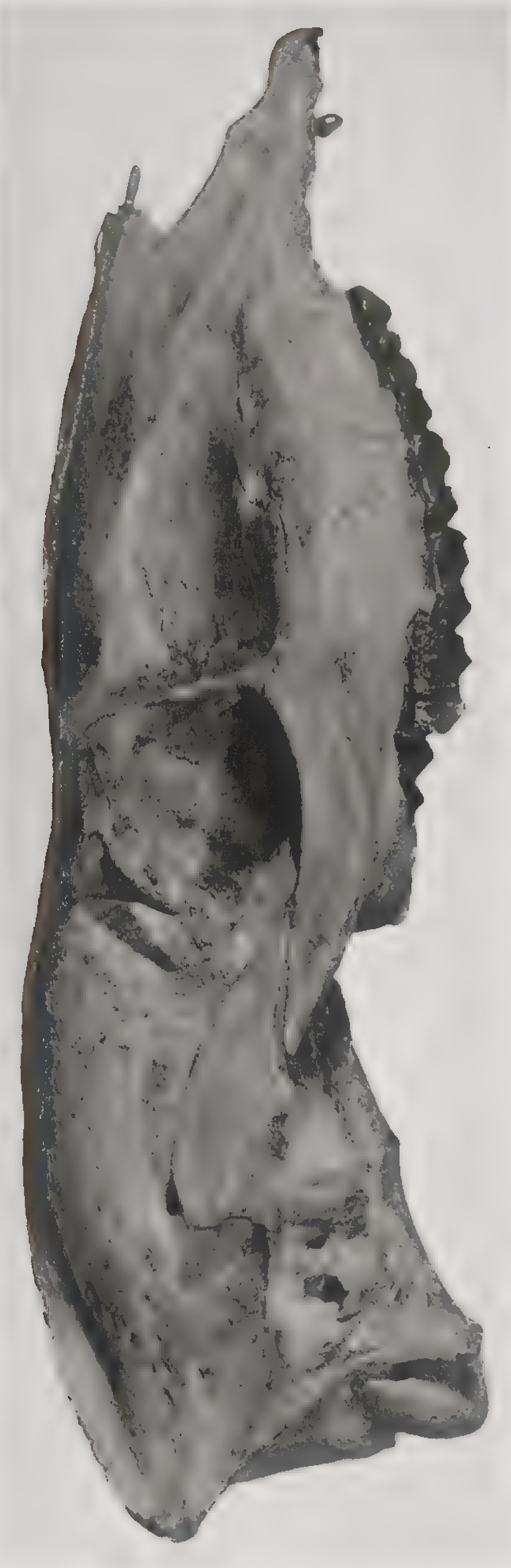


PLATE 18

PLATE 18

Hypohippus avus Schlaikjer

Type. Palatal view of skull. Two-thirds natural size.

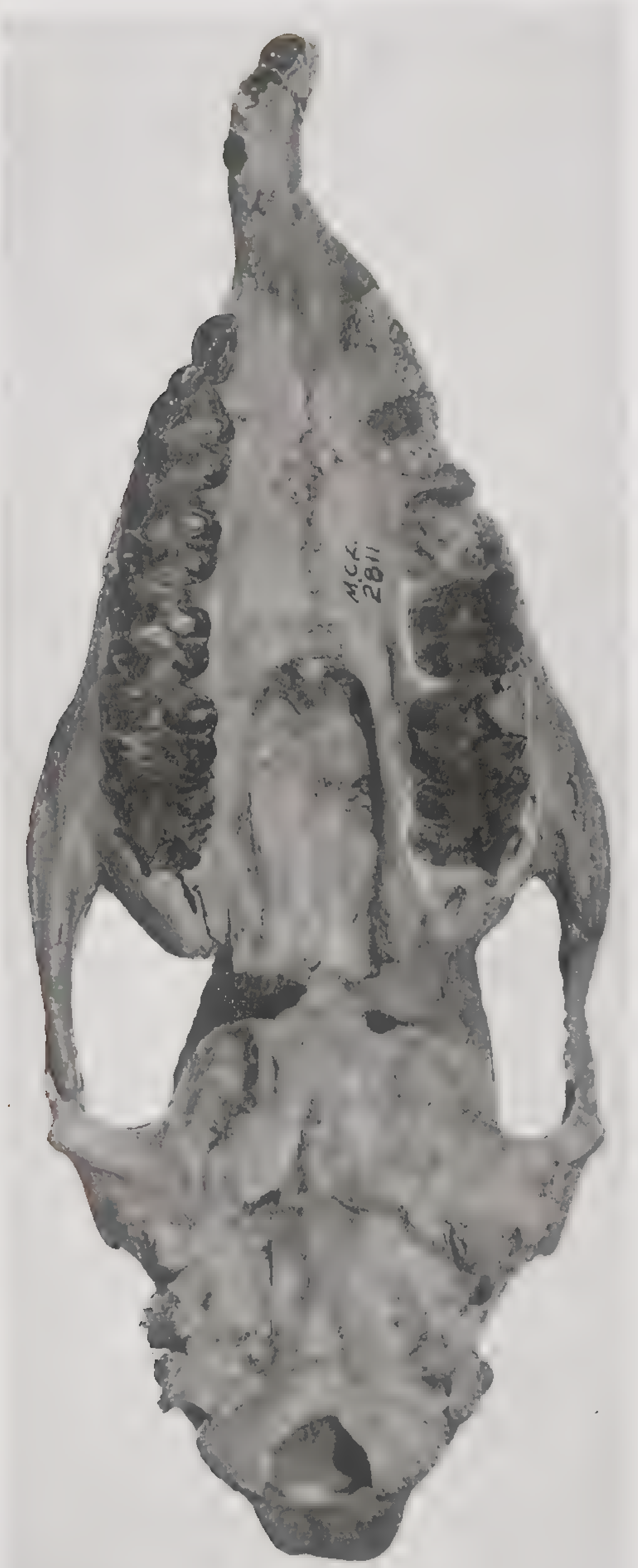

M.C.Z.
2811

PLATE 19

PLATE 19

Hypohippus avus Schlaikjer

Type. Dorsal view of skull. Two-thirds natural size.

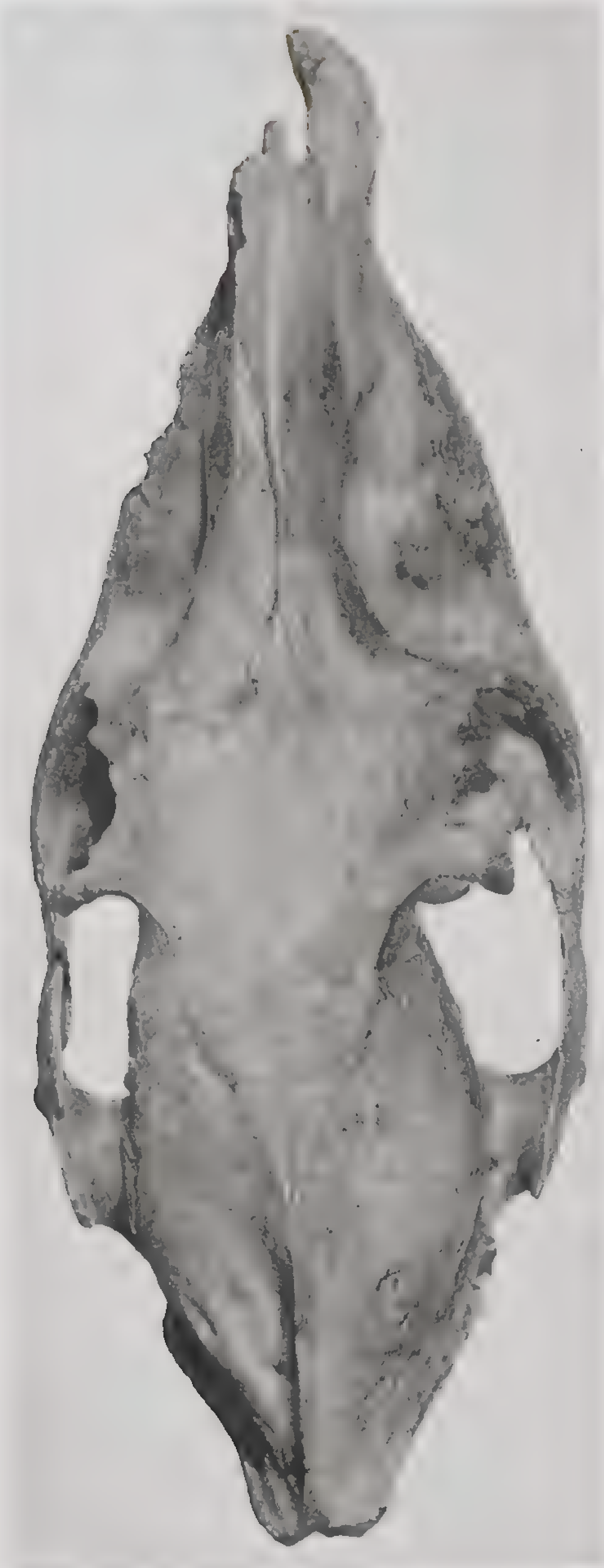


PLATE 20

PLATE 20

Archaeotherium palustris Schlaikjer

Type. Superior view of jaws. One-fourth natural size.

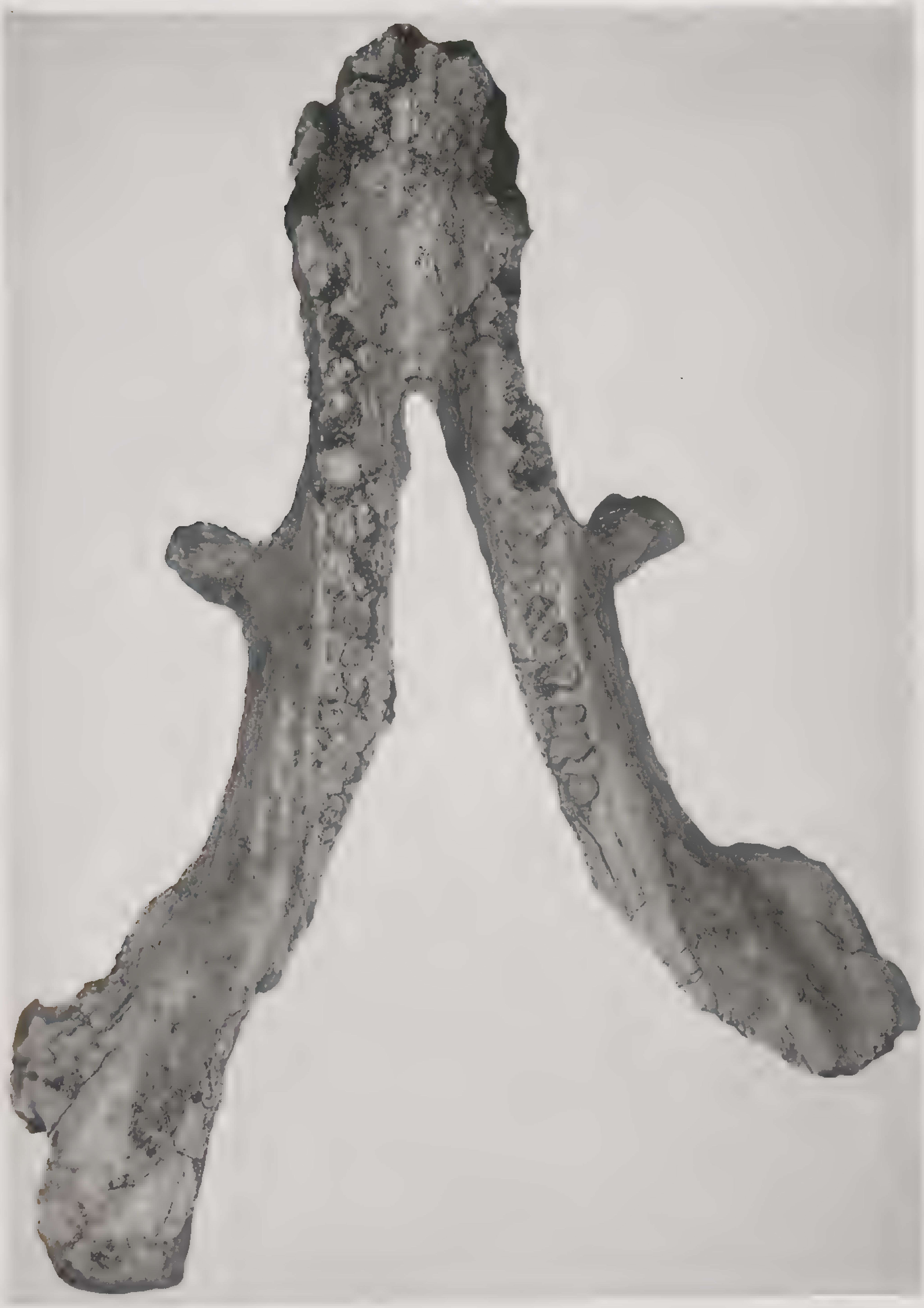


PLATE 21

PLATE 21

DINOHYUS MINIMUS Schlaikjer

Type. Superior view of symphysial region of the jaws. Three-fourths natural size.

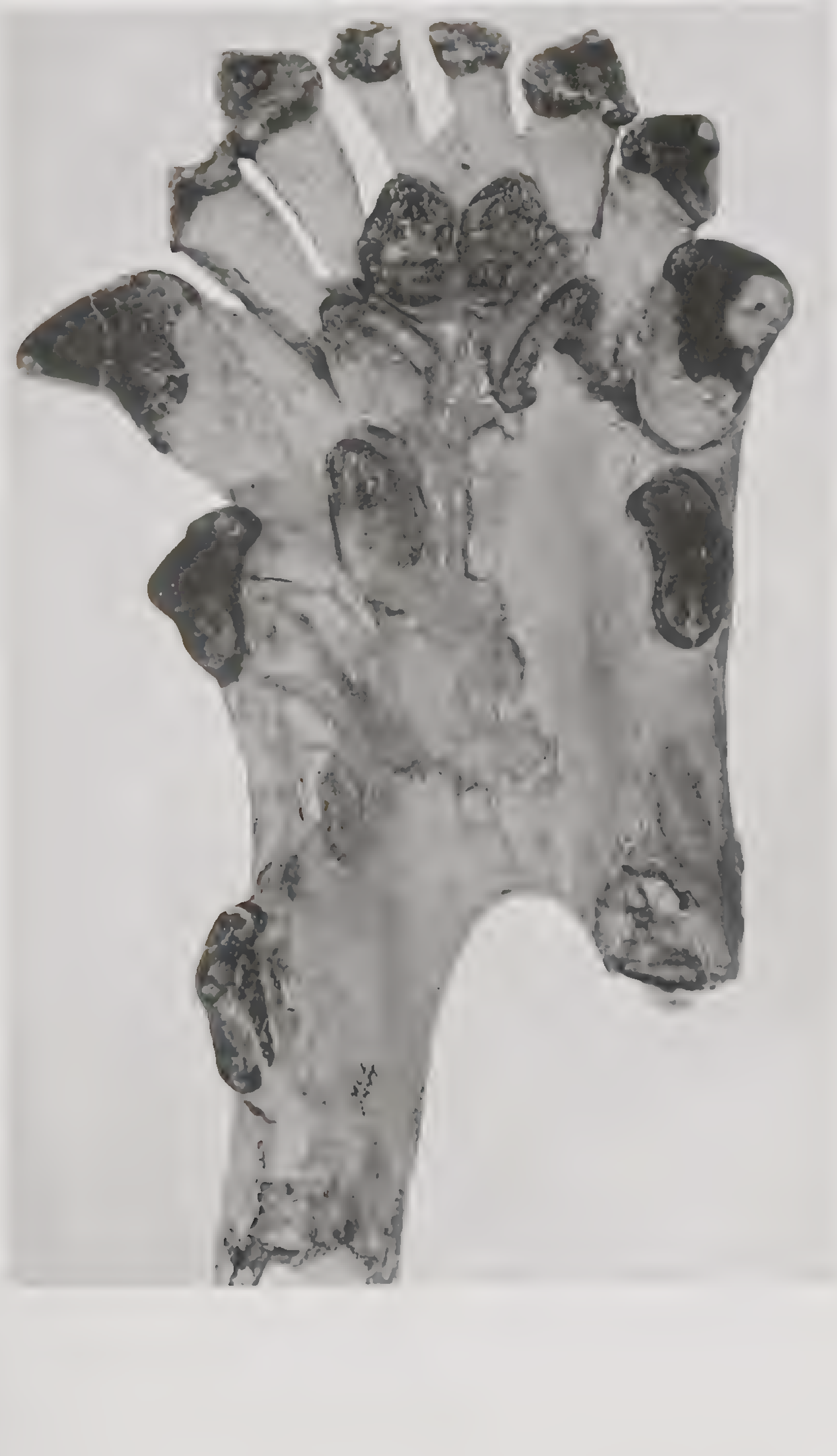


PLATE 22

PLATE 22

Fig. 1. *Cyclopidius heterodon* Cope. Neotype. Lateral view of skull.

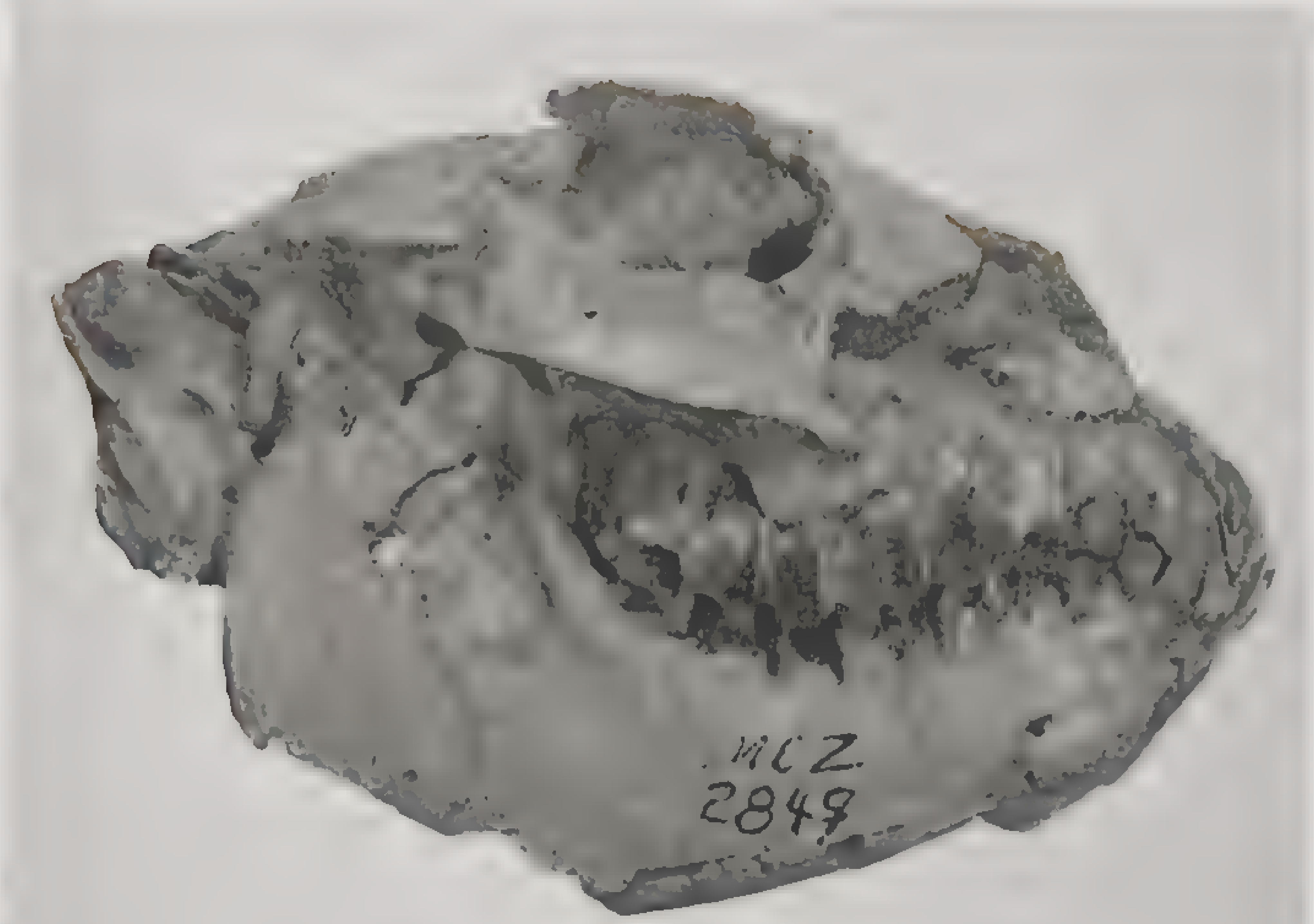
Fig. 2. *Cyclopidius heterodon* Cope. Referred specimen. Palatal view of P^1–M^3.

Fig. 3. *Cyclopidius heterodon* Cope. Referred specimen. Right maxilla.

Fig. 4. *Cyclopidius heterodon* Cope. Referred specimen. Right jaw.

Fig. 5. *Cyclopidius heterodon* Cope. Referred specimen. Metacarpal and first phalanx.

All figures natural size.



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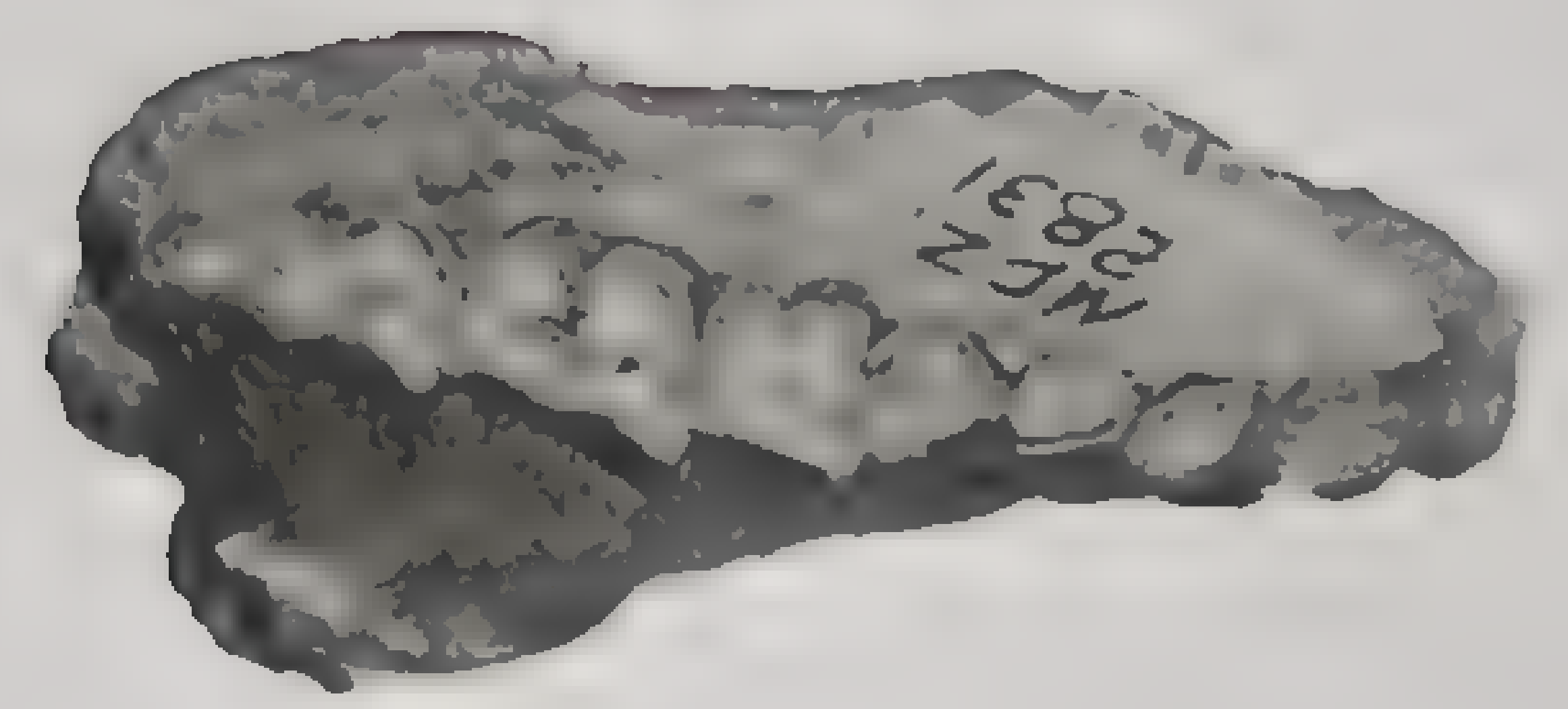
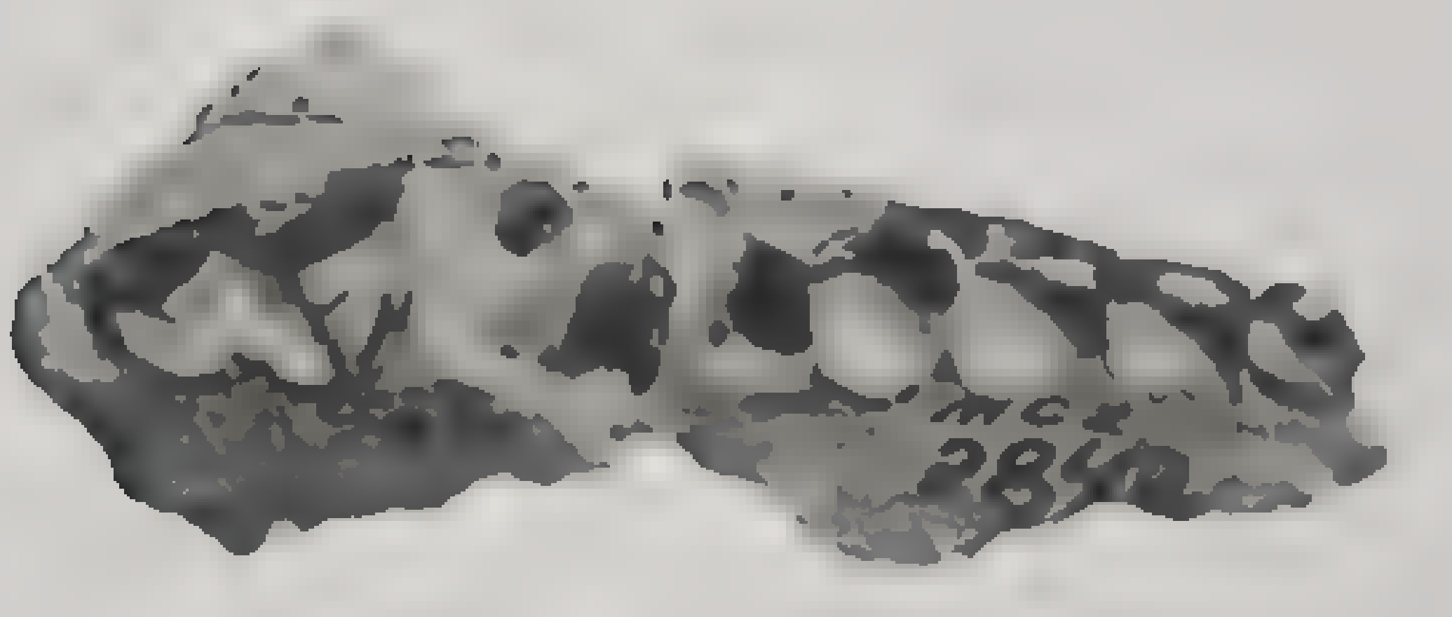


2

3



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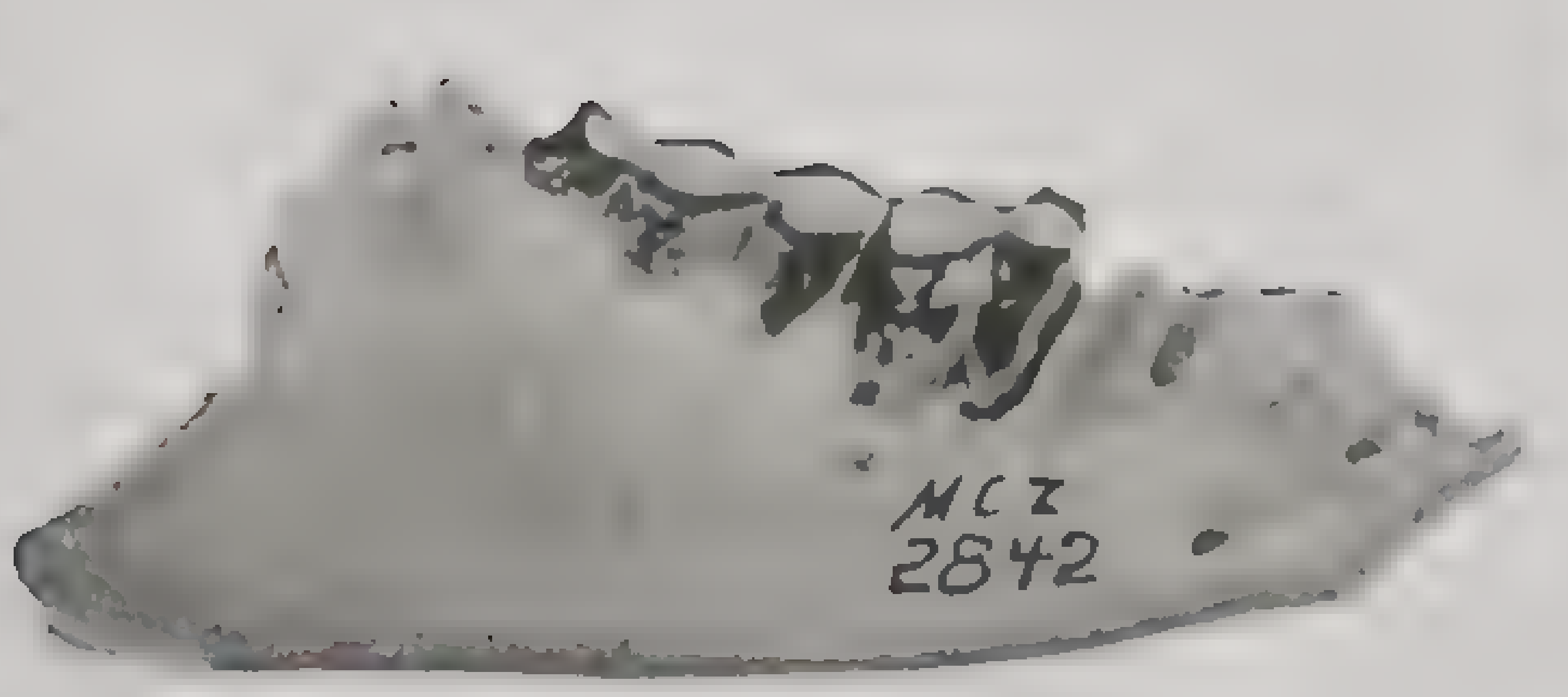
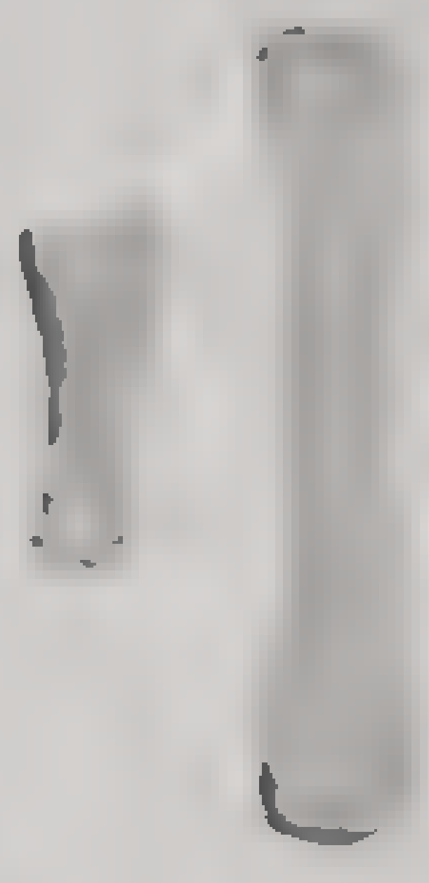




5

PLATE 23

PLATE 23

Cyclopidius heterodon Cope

Referred specimen. Dorsal, lateral and palatal views of the skull of a young individual. Natural size.

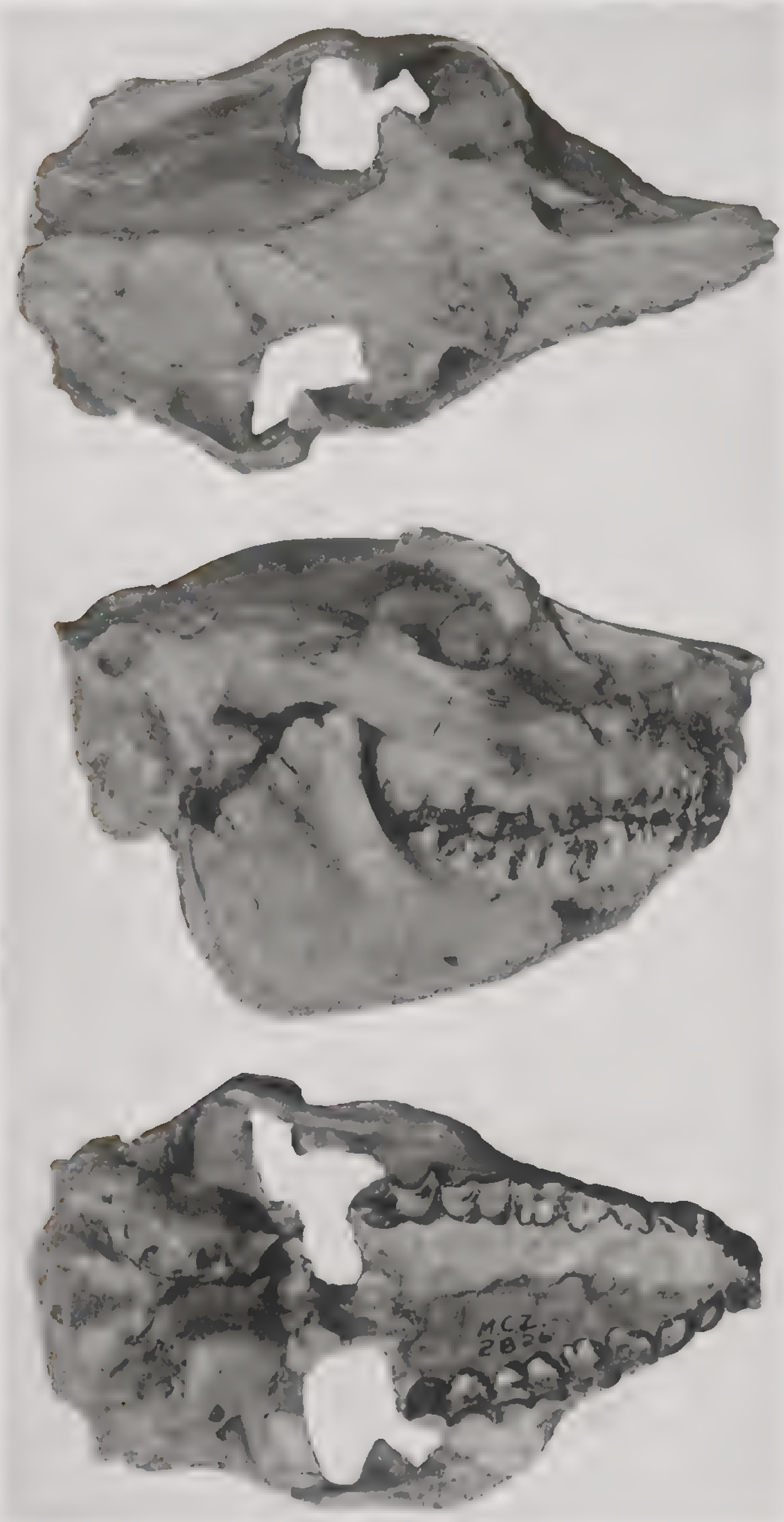

M.C.Z.
2826

PLATE 24

PLATE 24

Cyclopidius densa (Loomis)

Referred specimens. Two skulls. Three-fourths natural size.

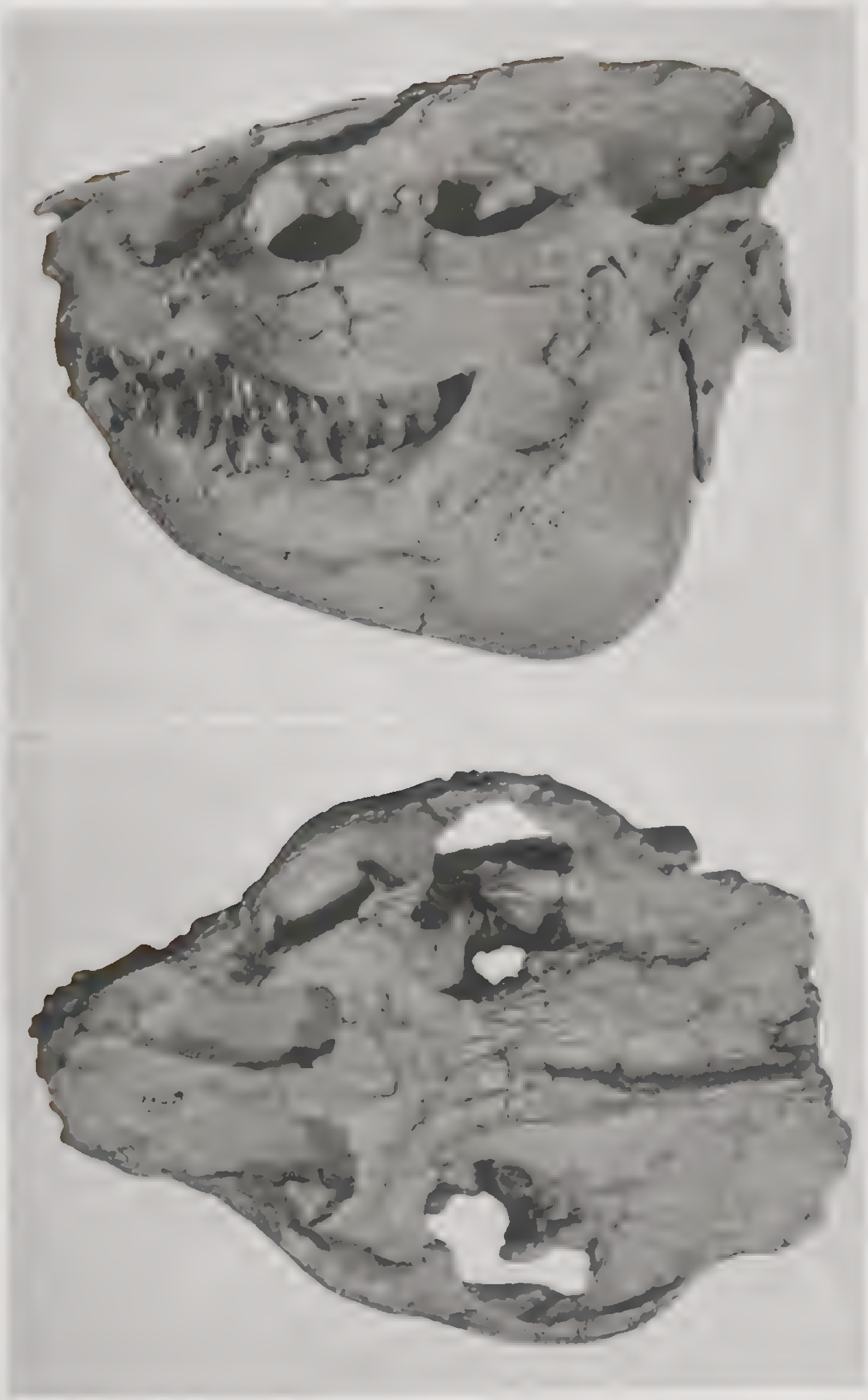


PLATE 25

PLATE 25

CYCLOPIDIUS DENSA (Loomis)

Referred specimens. Palatal views of dentitions of two individuals. Natural size.

Photographs, Plates 17–25, by W. L. Hallowell.

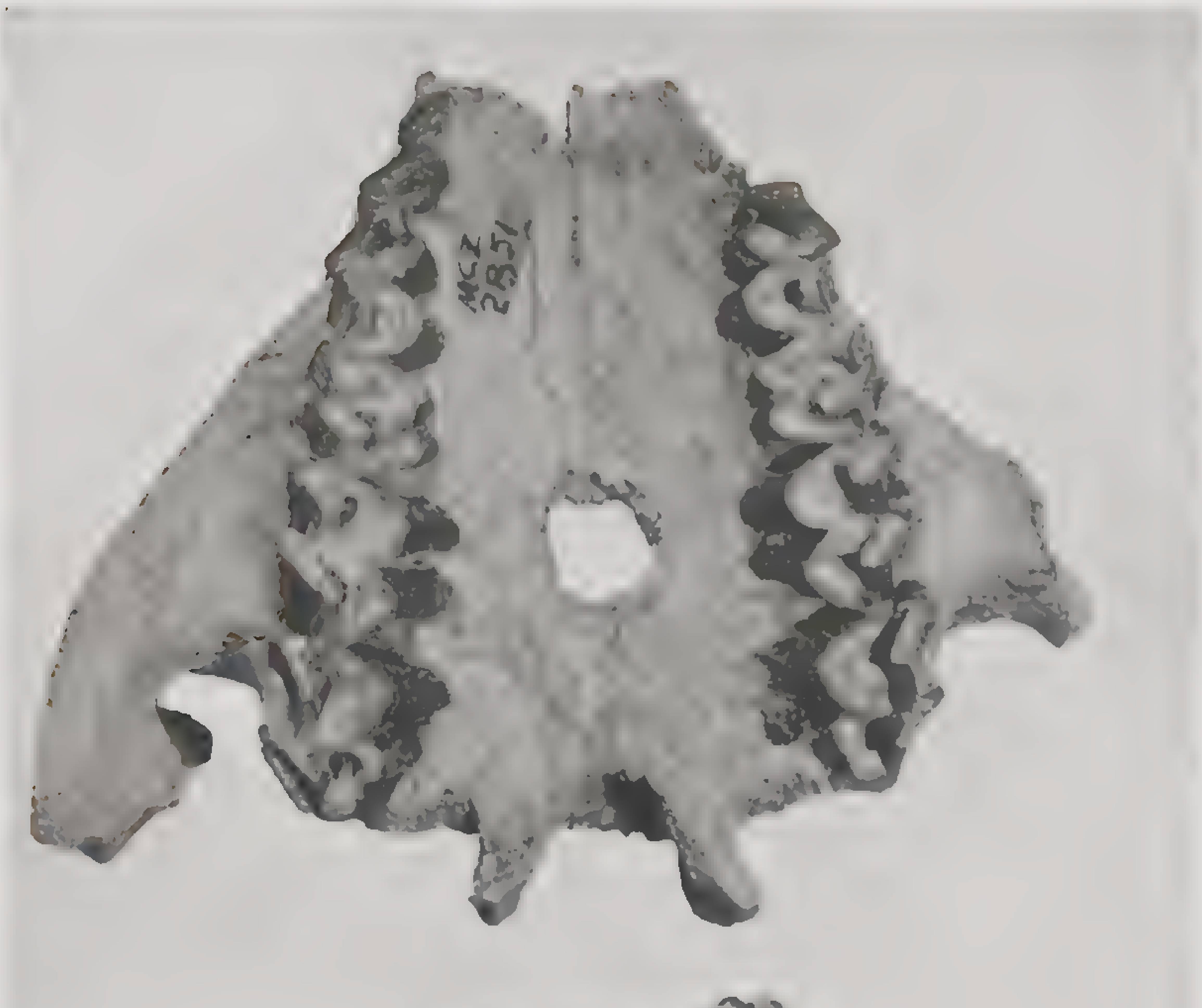

MCZ
2851

PLATE 26

PLATE 26

Fig. 1. *Cyclopidius emydinus* Cope. Type. Palatal view of the skull.

Fig. 2. *Cyclopidius heterodon* Cope. Type. Palatal view of P^4–M^1.

Fig. 3. *Cyclopidius simus* Cope. Type. Palatal view of the skull.

All Figures three-fourths natural size.

Photographs from the American Museum collection.

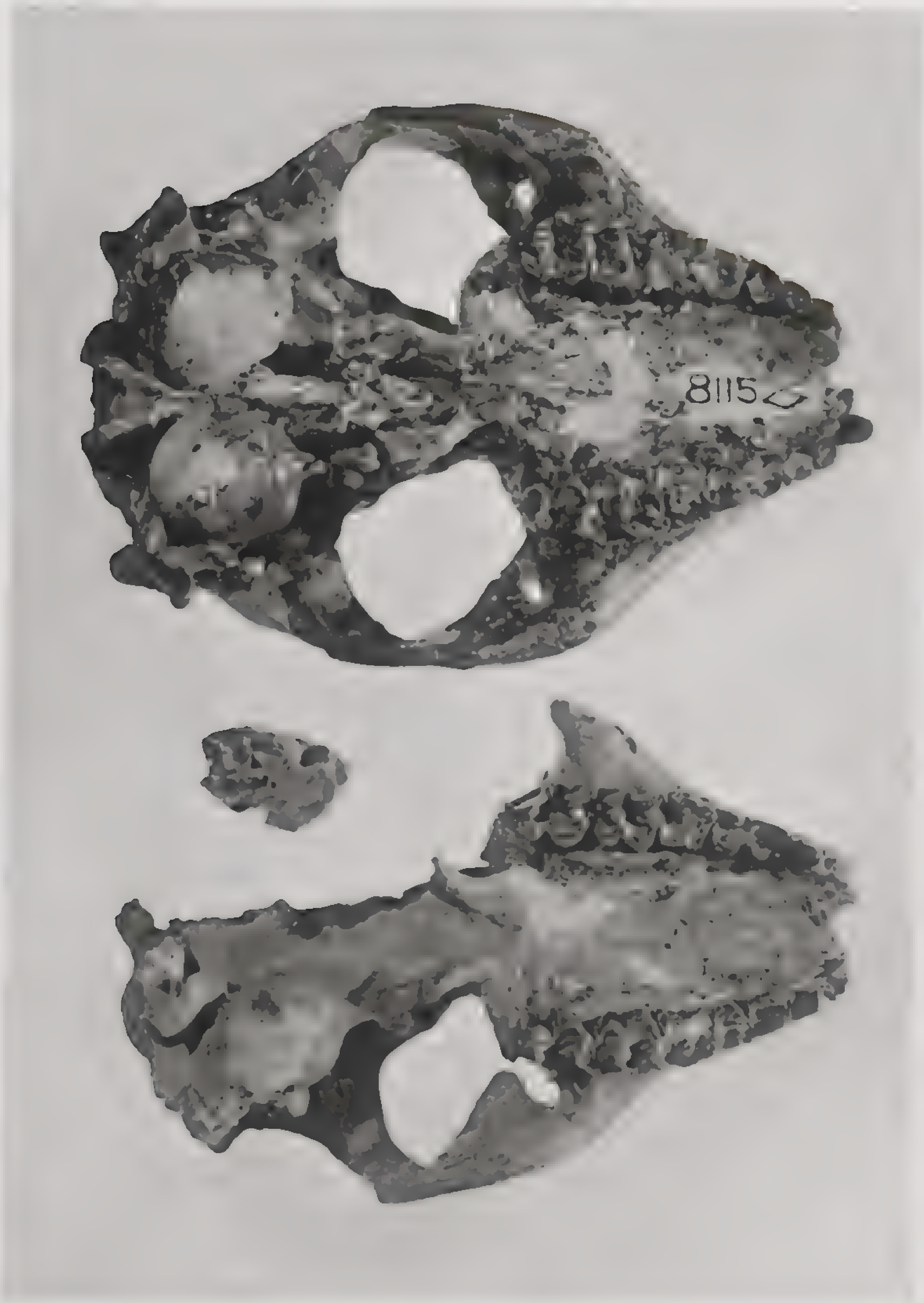

1
8115
2
3

PLATE 27

PLATE 28

Eporeodon cheeki Schlaikjer

Type. Palatal view of the skull. Five-ninths natural size.

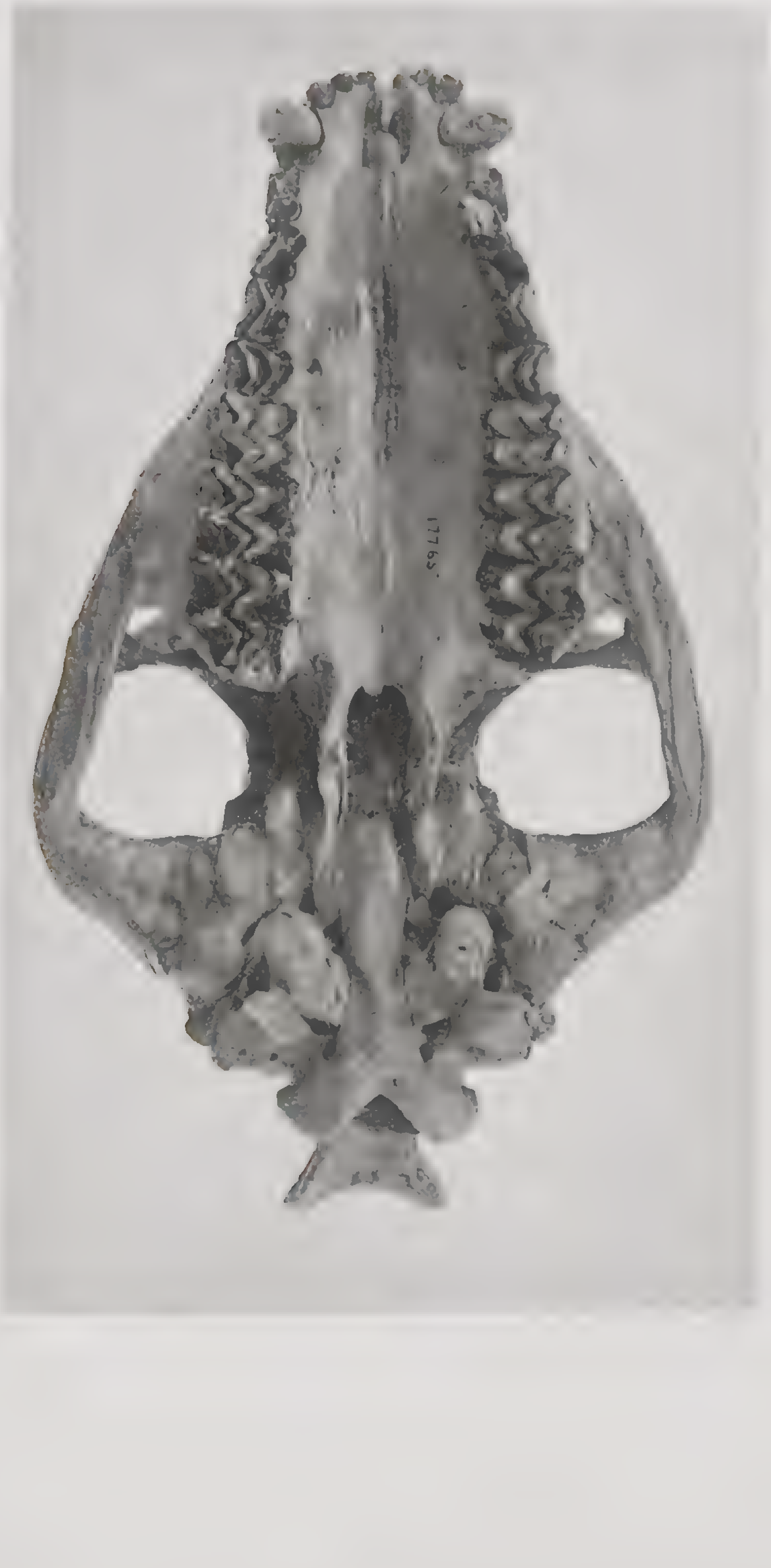

17765

PLATE 29

PLATE 29

Eporeodon cheeki Schlaikjer

Type. Left view of the skeleton. Approximately one-ninth natural size.

Photographs, Plates 27–29, by George Nelson.

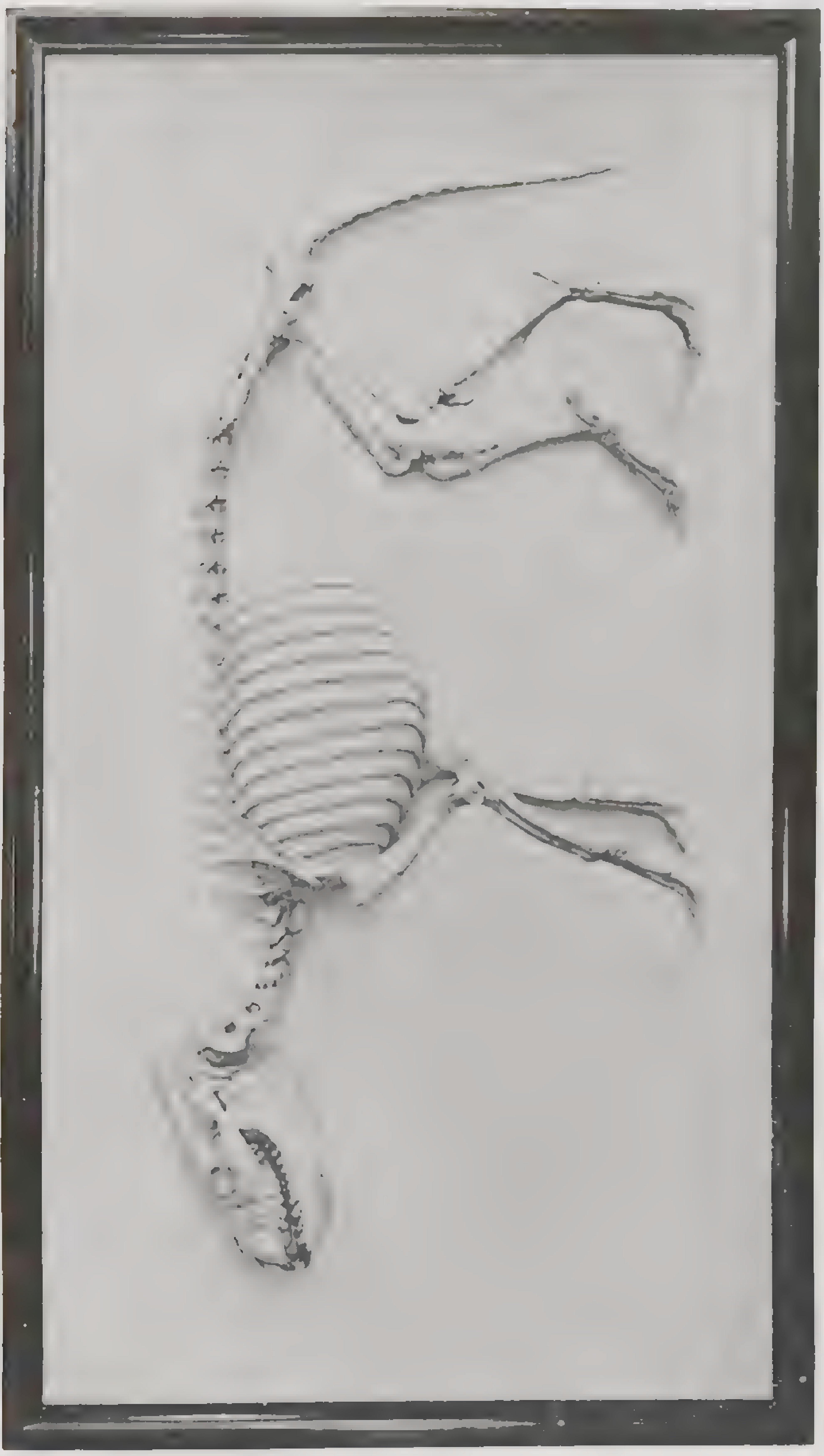


PLATE 30

PLATE 30

Mesoreodon chelonyx Scott

Referred specimen. Lateral and palatal views of the skull. Two-thirds natural size.

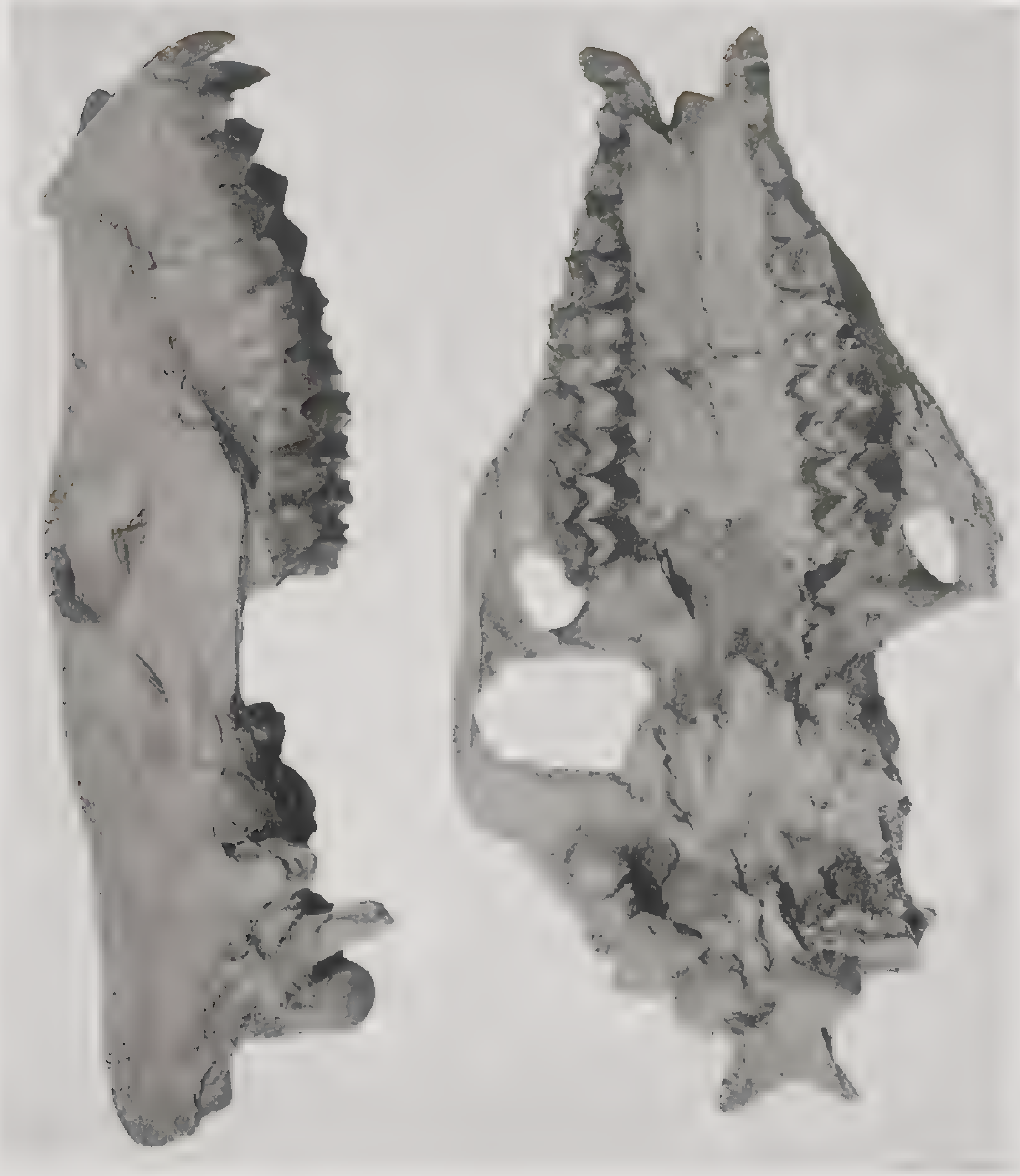


PLATE 31

PLATE 31

Mesoreodon megalodon Peterson

Referred specimen. Lateral view of the skull. Two-thirds natural size.

Photographs, Plates 30–31, by W. L. Hallowell.

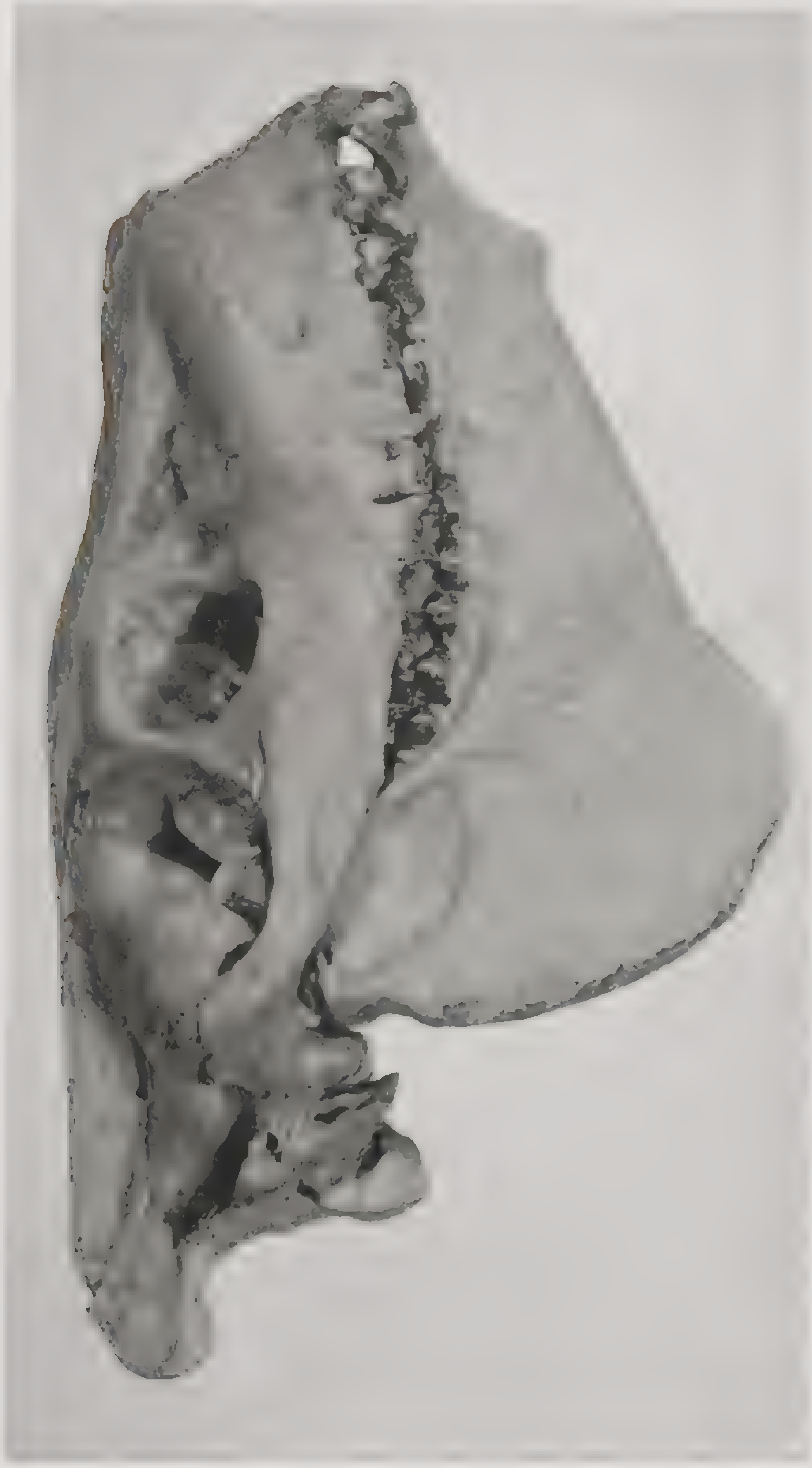


PLATE 32

PLATE 32

MESOREODON SCOTTI Schlaikjer

Type. Lateral view of the skeleton. One-ninth natural size.

Photograph by George Nelson.

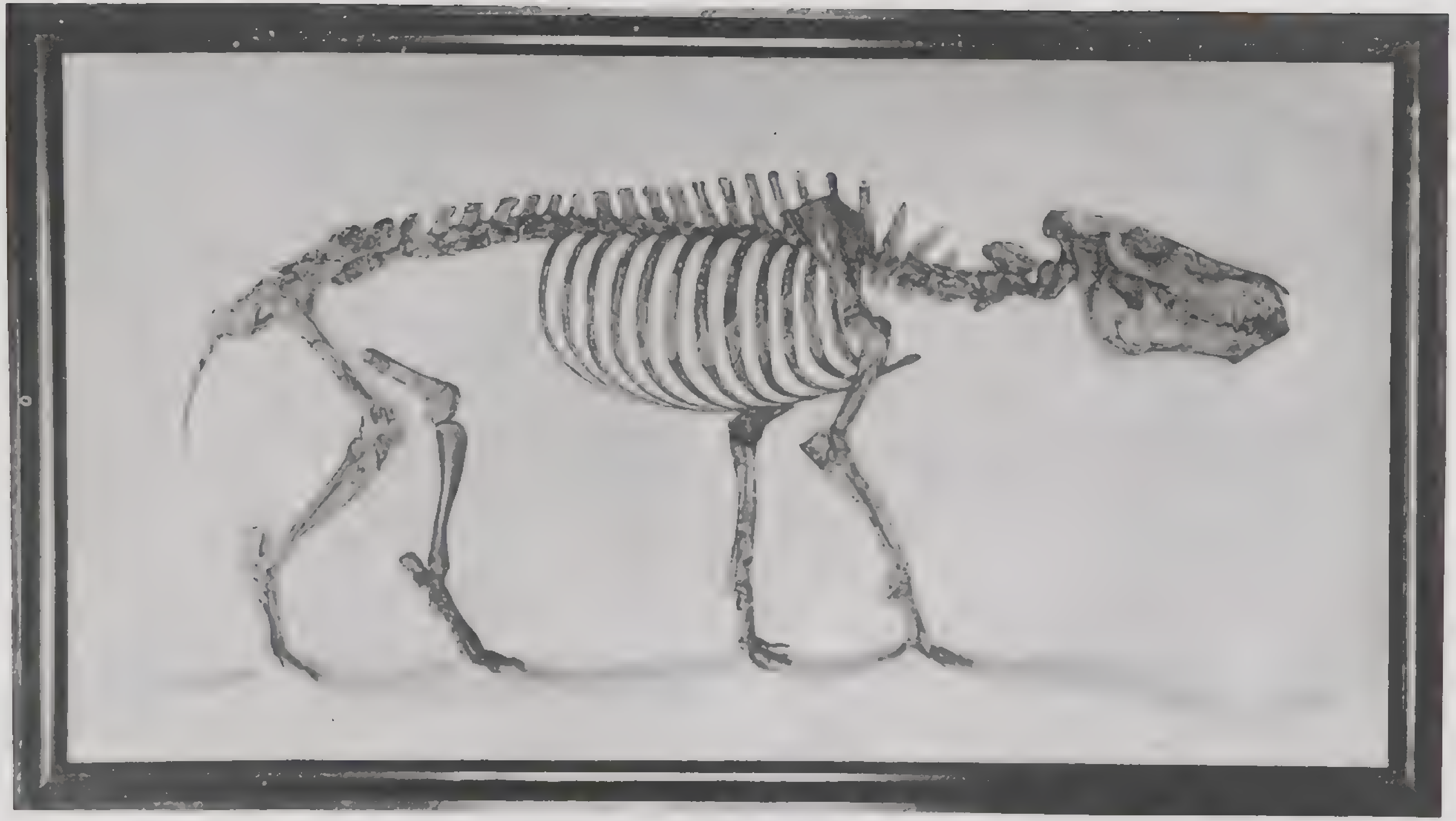


PLATE 33

PLATE 33

Promerycochoerus loomisi Schlaikjer

Type. Dorsal view of the skull. Three-eighths natural size.

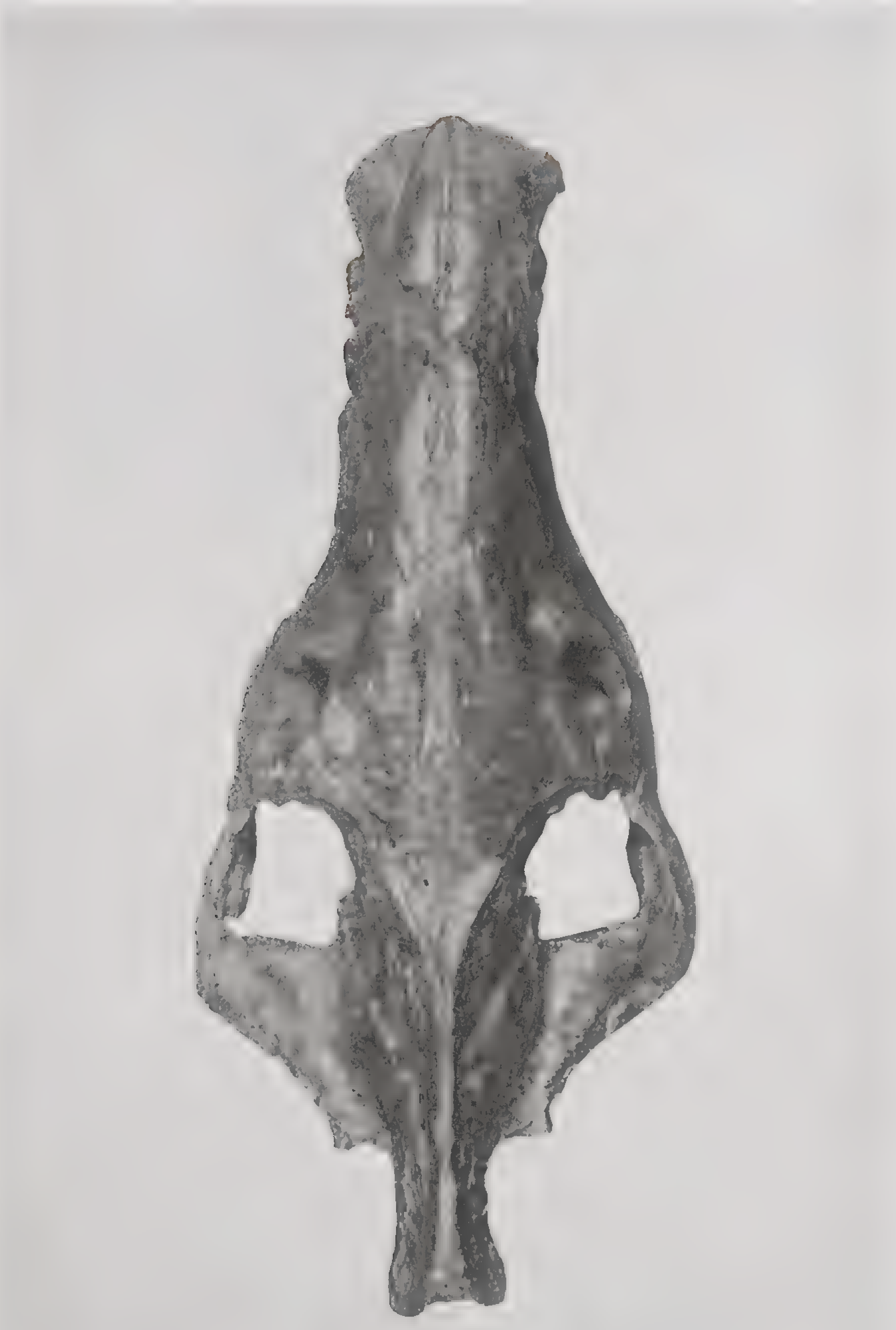


PLATE 34

PLATE 34

Promerycochoerus loomisi Schlaikjer

Type. Lateral view of the skull. Three-eighths natural size.

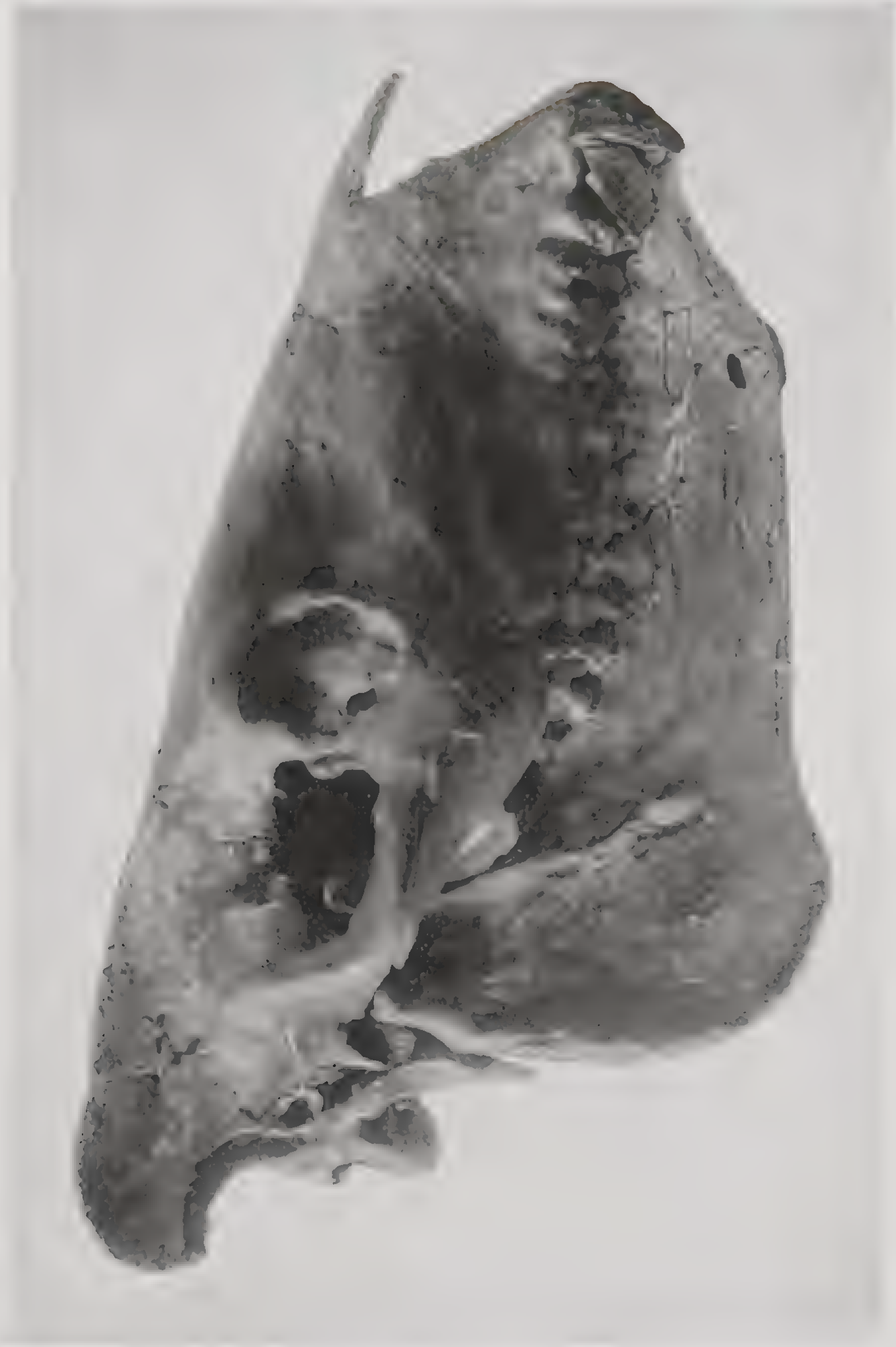


PLATE 35

PLATE **35**

Promerycochoerus loomisi Schlaikjer

Type. Lateral view of the skeleton. One-twelfth natural size.

Photographs, Plates 33–35, by F. P. Orchard.

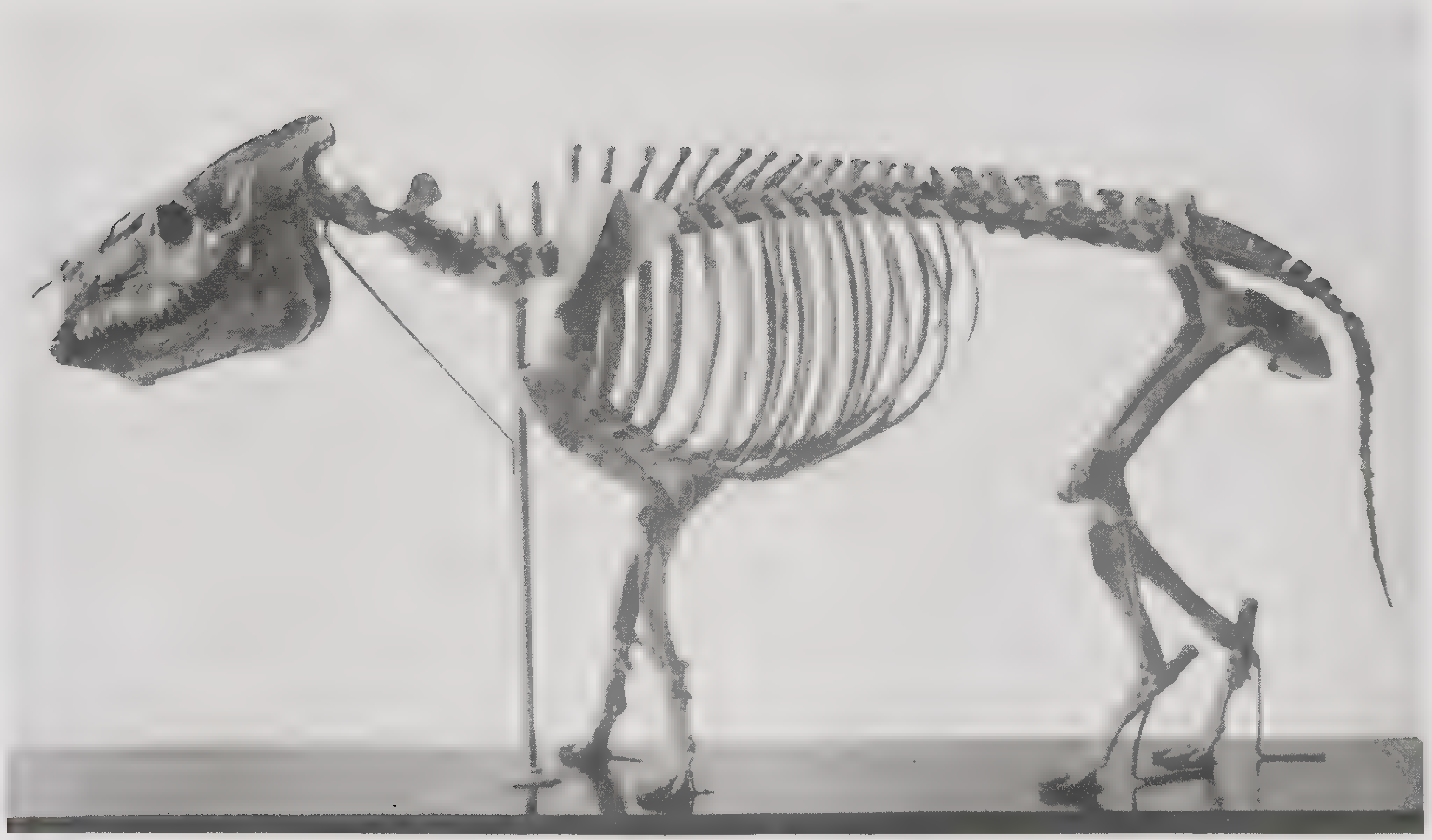


PLATE 36

PLATE 36

PROMERYCOCHOERUS HATCHERI Douglass

Referred specimen. Dorsal view of the skull of male. One-half natural size.

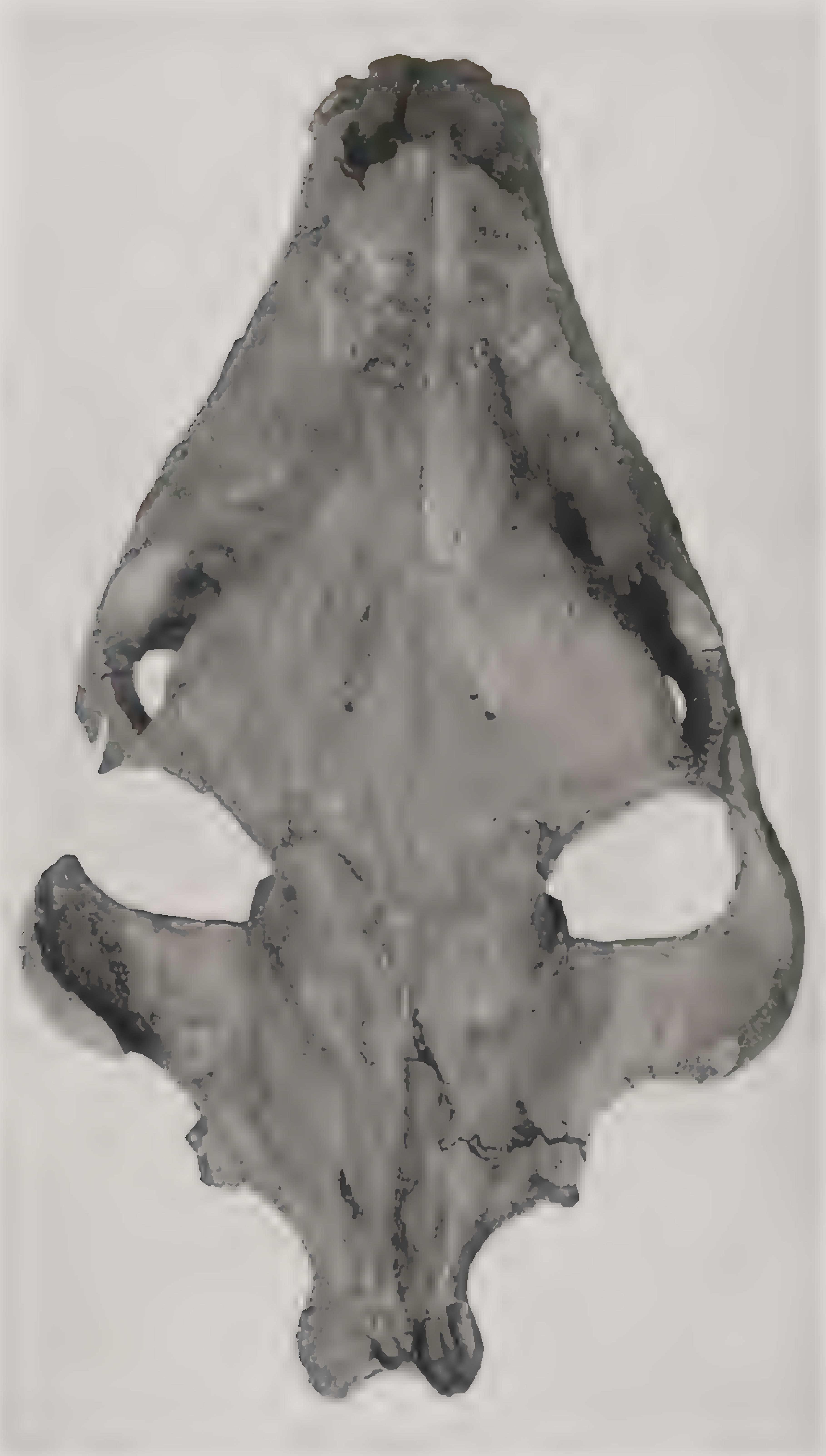


PLATE 37

PLATE 37

Promerycochoerus hatcheri Douglass

Referred specimen. Palatal view of the skull of male. One-half natural size.

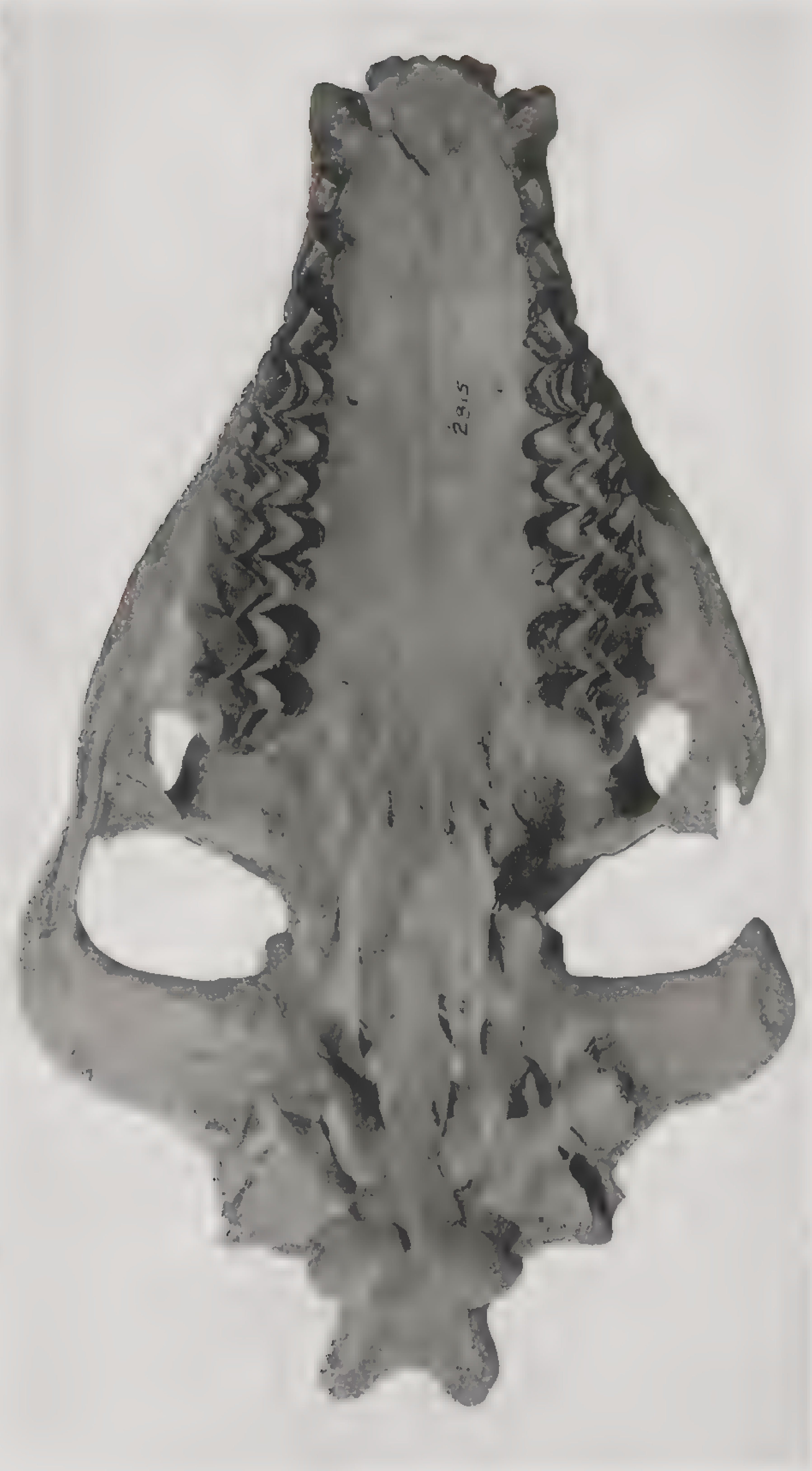

2915

PLATE 38

PLATE 38

Promerycochoerus hatcheri Douglass

Referred specimen. Lateral view of the skull of female.

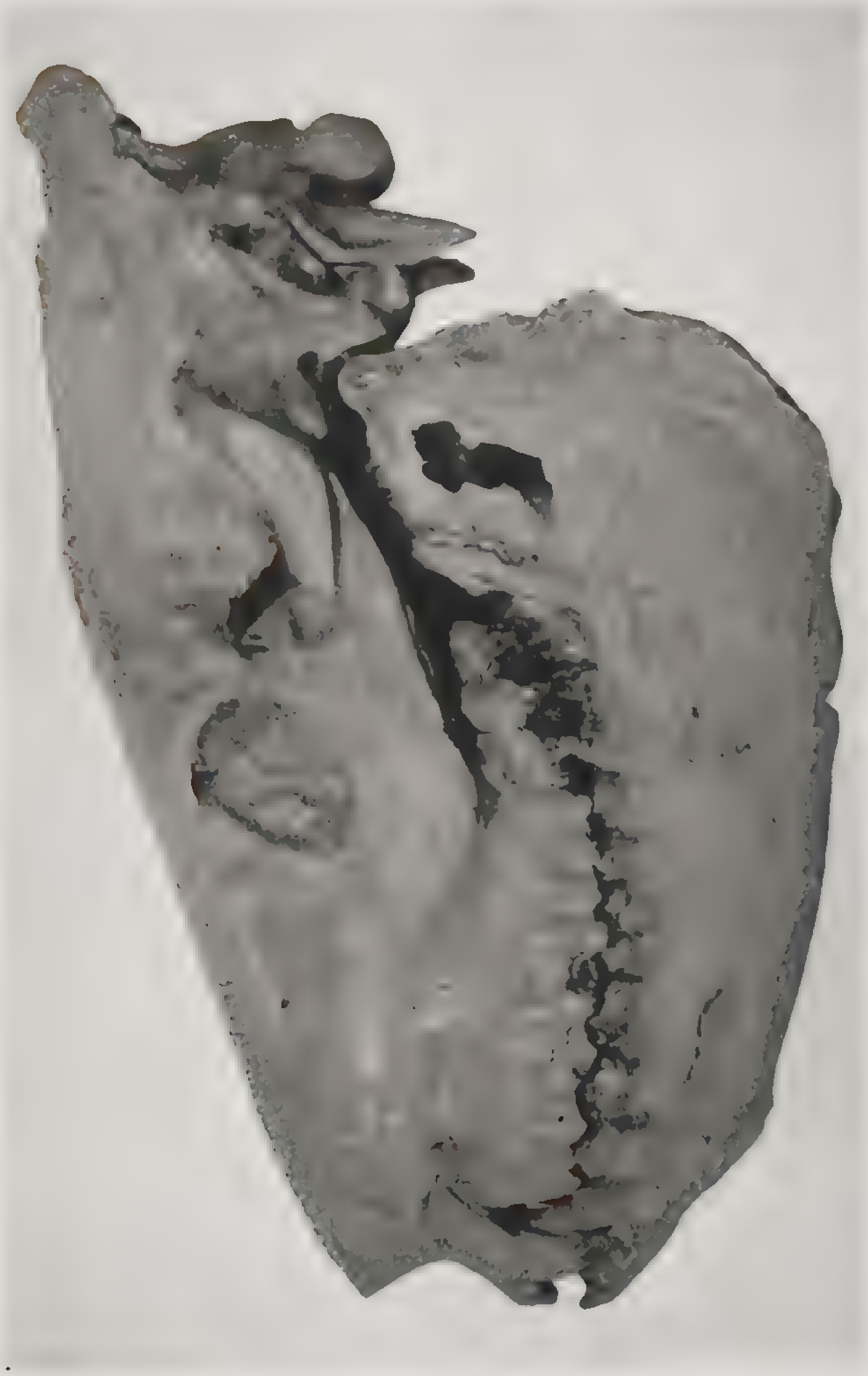


PLATE 39

PLATE 39

MIOTYLOPUS BATHYGNATHUS Schlaikjer

Genoholotype. Dorsal, lateral and palatal views of the skull and jaws. One-half natural size.

Photographs, Plates 36–39, by W. L. Hallowell.

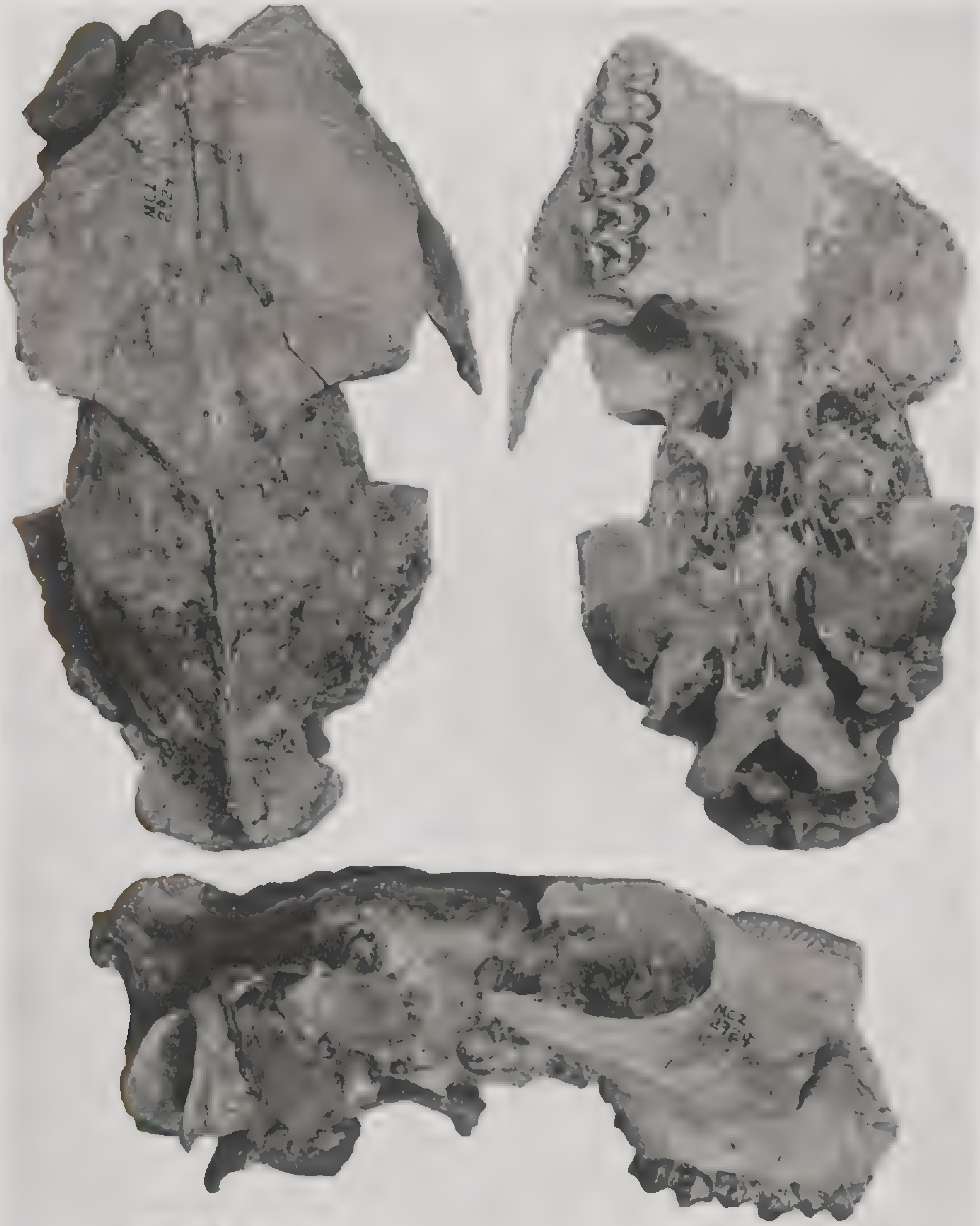

MCZ 2724
MCZ 2724

PLATE 40

PLATE 40

NANOTRAGULUS INTERMEDIUS Schlaikjer

Type. Dorsal, lateral and palatal views of the skull and jaws. Natural size.

Photographs by Albert Thompson.

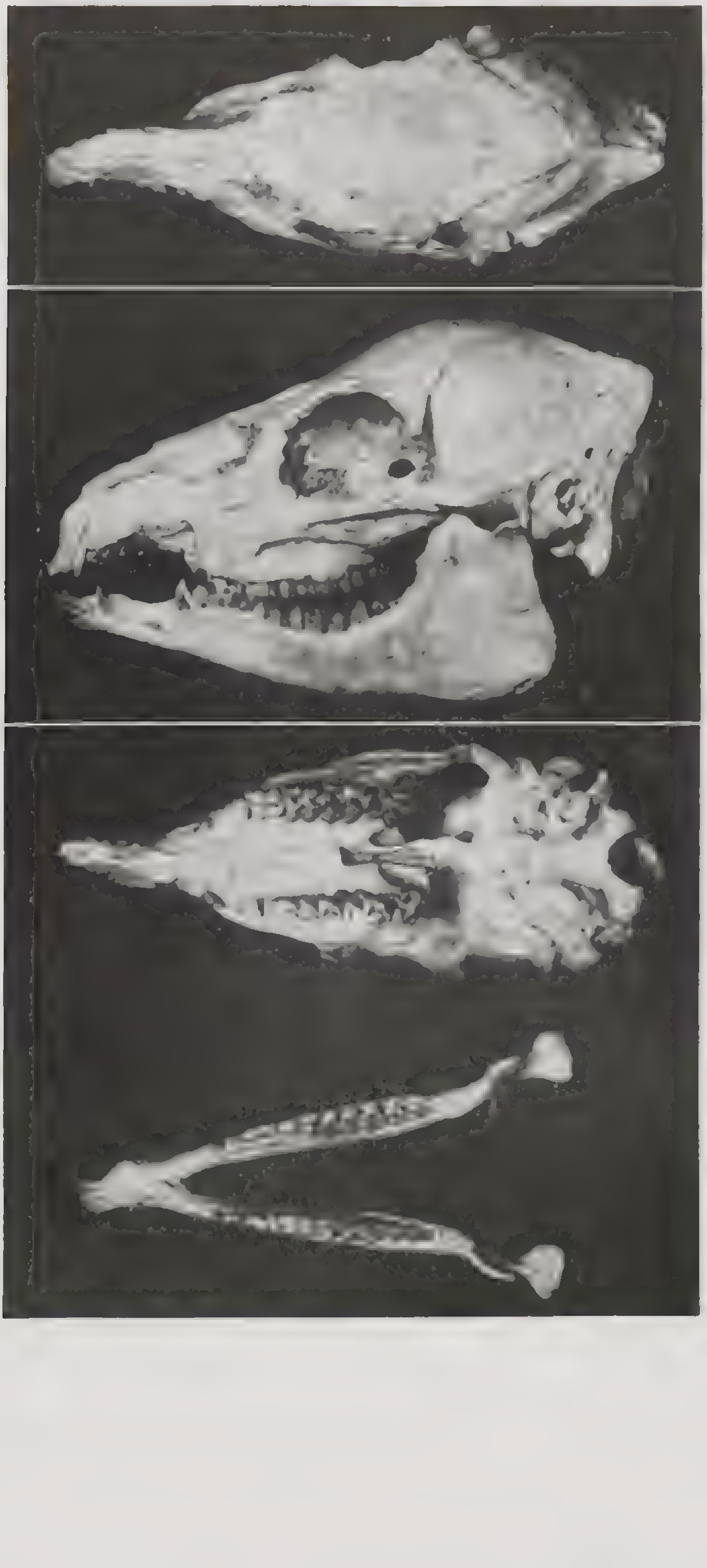


PLATE 41

PLATE 41

Fig. 1. *Subhyracodon occidentale* (Leidy). Referred specimen. Palatal view of P^1–M^3. One-half natural size.

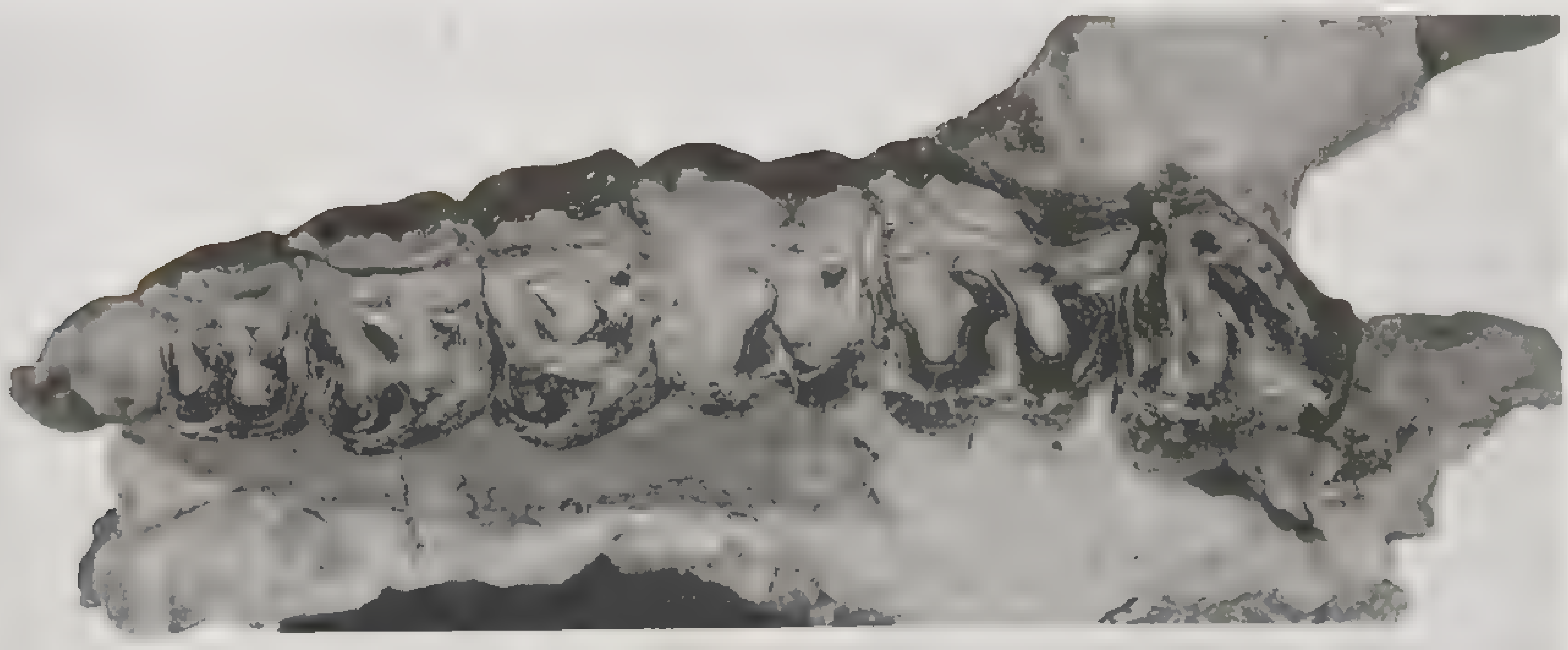
Fig. 2. *Parahippus ?pristinus* Osborn. Referred specimen. Palatal view of DP^{2-4}. Natural size.

Fig. 3. *Merychyus harrisonensis* Peterson. Referred specimen. Palatal view of P^2–M^3. Natural size.

Fig. 4. *Nanotragulus intermedius* Schlaikjer. Paratype. Palatal view of the skull. Natural size.

Fig. 5. *Leptauchenia minora* Schlaikjer. Type. Palatal view. Natural size.

Fig. 6. *Leptotragulus ultimus* Schlaikjer. Type. Palatal view of M^3. Natural size.



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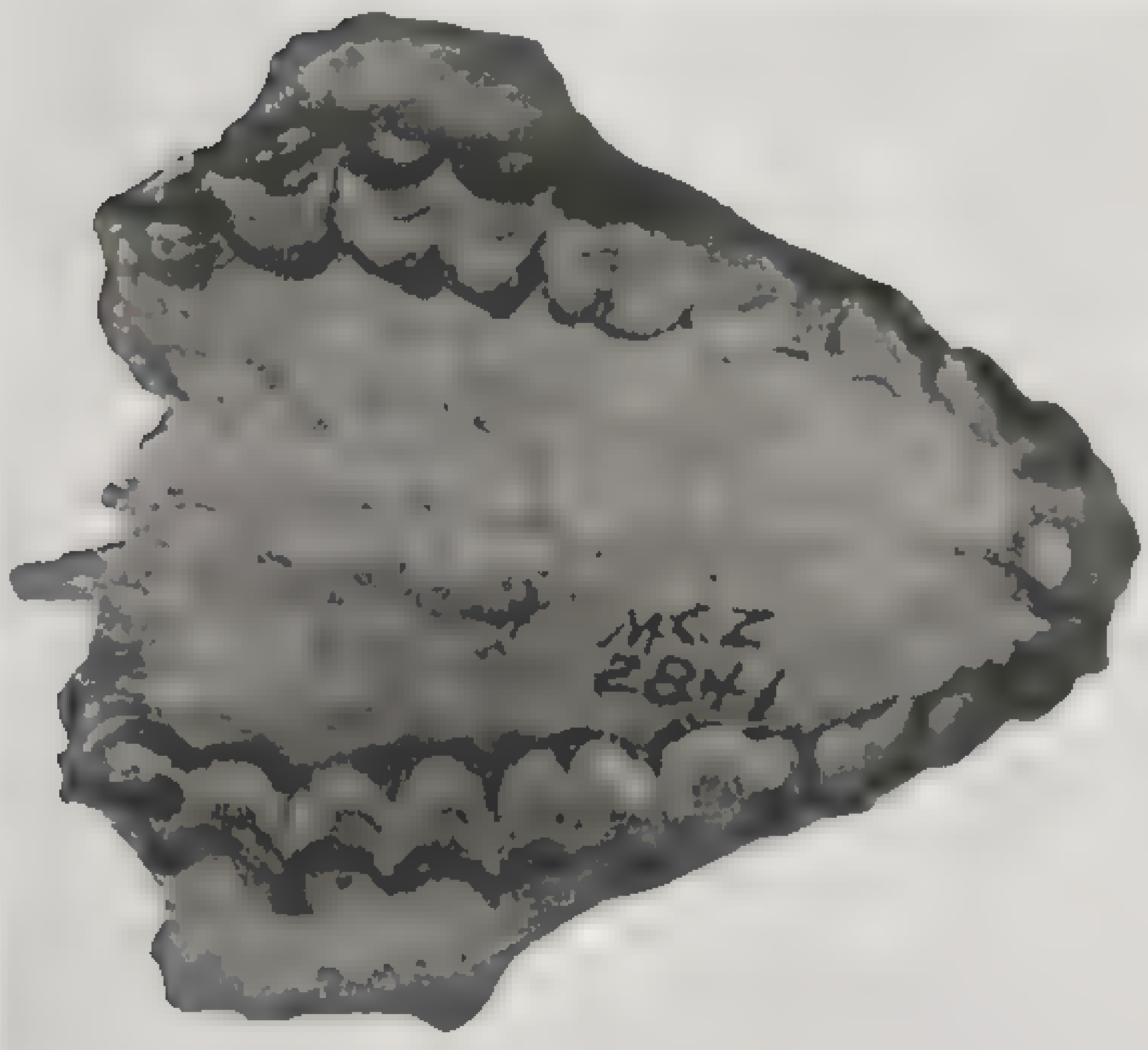

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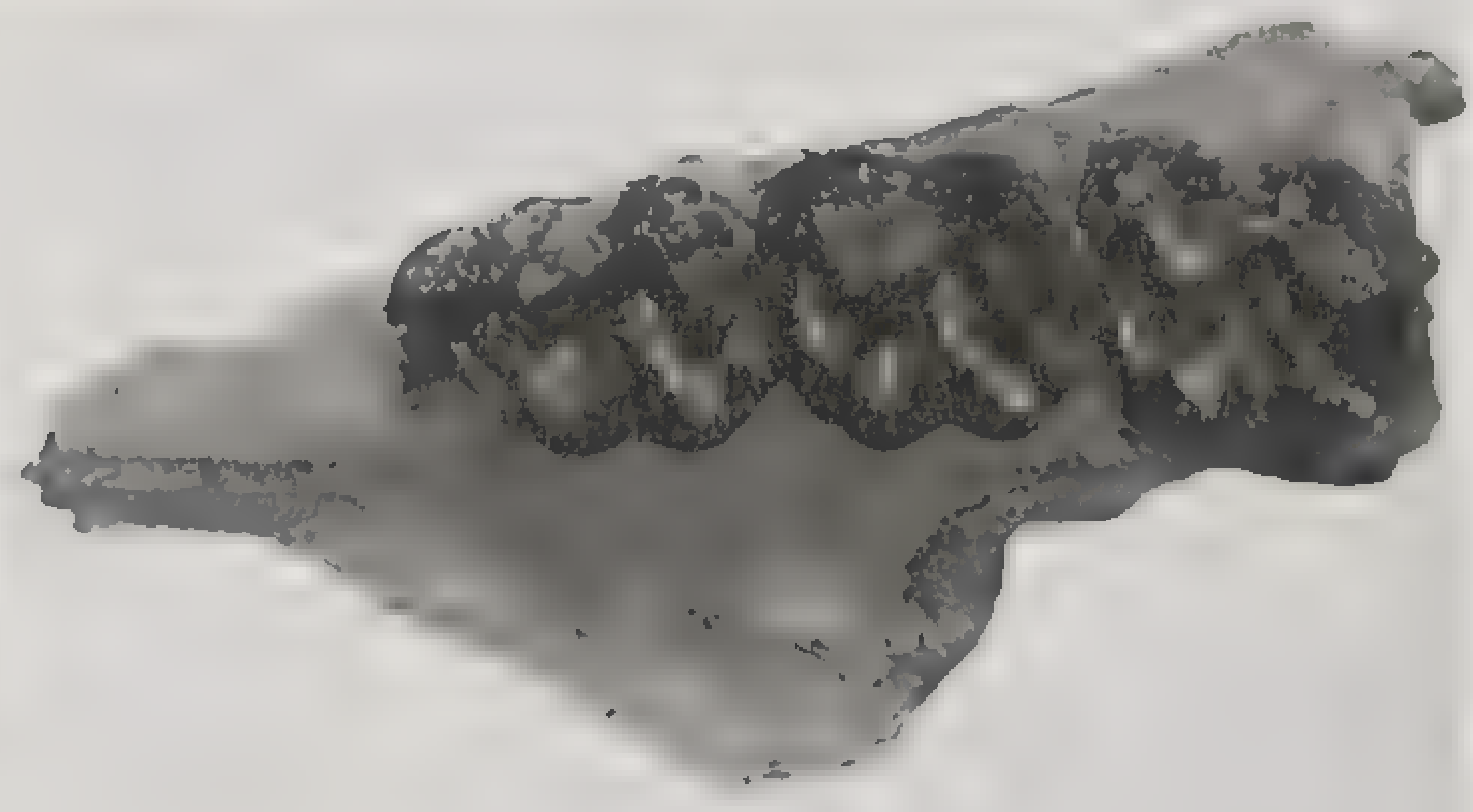

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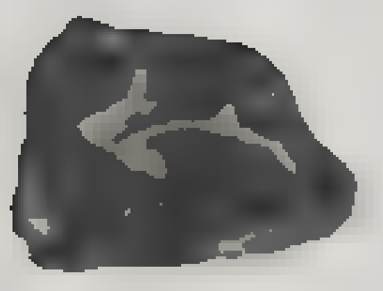

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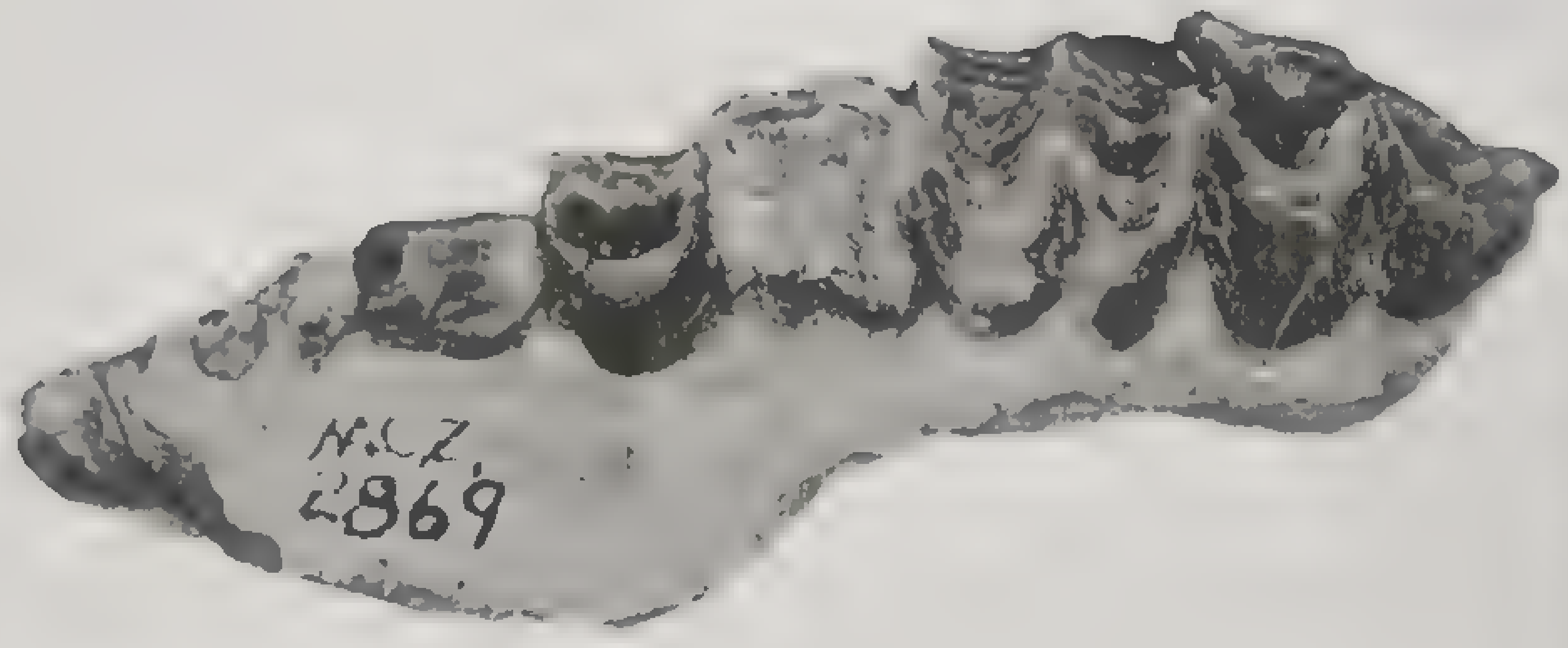

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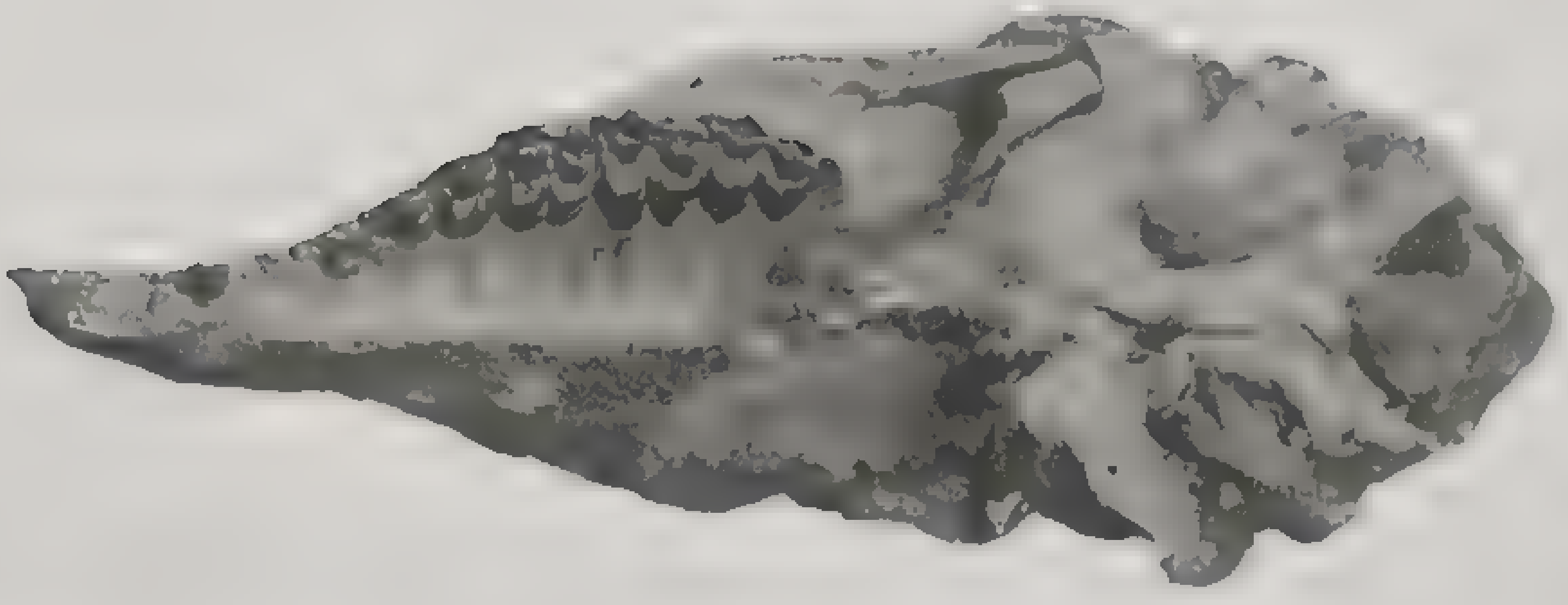

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Bulletin of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE
Vol. LXXVI, No. 5

SHALER MEMORIAL SERIES

SOME ORDOVICIAN CYSTIDS FROM RUSSIA

By Fred B. Phleger, Jr.

With One Plate

CAMBRIDGE, MASS., U. S. A.
PRINTED FOR THE MUSEUM
July, 1935

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No. 5.— *Some Ordovician Cystids from Russia*

By Fred B. Phleger, Jr.

INTRODUCTION

In 1914 Professor Percy E. Raymond, on a Shaler Memorial Expedition, made large collections from several localities of the Ordovician strata of Russia. The following paper describes the new cystids represented in the collection and redescribes some of the established forms. The writer is grateful to Professor Raymond for the use of the specimens and for his generous aid in the preparation of this paper.

Most of the material was obtained from quarries and all the good specimens are from weathered debris not in place. It is believed that most of the cystids are from Lamansky's[1] zone $B_{III\alpha}$ but some are probably from his zone $B_{III\beta}$. Lamansky's $B_{III\alpha}$ is the equivalent of the upper part of Raymond's[2] Walchow formation and $B_{III\beta}$ is the lower part of the Kunda formation. It is doubtful if any of the material came from any lower in the section than the zone $B_{III\alpha}$.

Phylum Echinodermata Stachelhauter

Class CYSTOIDEA Beutelstrahler

Order AMPHOROIDEA Haeckel

Family DENDROCYSTIDAE Bather

Genus Rhipidocystis Jaekel

RHYPIDOCYSTIS GIGAS Jaekel

Plate 1, fig. 9

Rhipidocystis gigas Jaekel, Zeitschrift der Deutschen geol. Gesell., 1900, p. 672. Bather, F. A., Caradocian Cistidea from Girvan, Trans. Royal Soc. Edinburgh, 1913, pp. 369–370.

Bather lists the published specimens which have been referred to this species, and also the holotype of *Rhipidocystis hallica* which he refers to *R. gigas*. None of the specimens so far figured shows the anus. One specimen in the present collection exhibits the anal side of the theca. Jaekel states that the forms included in his family Rhipidocystidae have a simple anal cavity between three plates. Moreover, in the definition of the only genus of that family, *Rhipidocystis,* he describes the anus as small and round. But in the definition of *R. gigas,* the only species of the family, no mention is made of the anus. Evidently none of the specimens studied by Jaekel exhibited the anal area, and his description of the anus in the family and genus was by inference only.

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[1] Lamansky, von W., Die Aeltesten Silurischen Schichten Russlands, 1905, p. 171.

[2] Raymond, P. E., The Correlation of the Ordovician Strata of the Baltic basin with those of Eastern North America, Bull. Mus. Comp. Zool., 1916, **41**, no. 3, pp. 188–195.

The anal pyramid is large, circular, convex, and enclosed by five thecal plates. It has a diameter of about 10 mm. It is composed of 18 to 25 wedge-shaped plates, about one-third of which reach the center of the area; small plates are wedged in between the larger ones. No idea of the shape of the theca is given by the fragmentary specimen at hand. The plates are thin and vary somewhat in size, but most are about 20 to 25 mm. in width. They are smooth with the exception of very faint axial ridges on a few plates.

The author is following Bather's suggestion that this genus is probably to be included in the family Dendrocystidae.

Formation and locality: Walchow and Kunda formations, Iswos, U.S.S.R.

The plesiotype is Mus. Comp. Zoöl. no. 4002.

Order RHOMBIFERA Bather

Superfamily GLYPTOCYSTIDAE Bather

Family ECHINOENCRINIDAE Bather

Genus ECHINOENCRINITES von Meyer

Echinoencrinites von Meyer, Karstens Archiv für Naturlehre, 1826, Bd. VII, p. 185. Jaekel, Otto, Stammesgeschichte der Pelmatozoen, Berlin, 1899, p. 242.

Echinoencrinus Bather, F. A., A Treatise on Zoölogy, pt. III, The Echinodermata, London, 1900, p. 60, figs. 22, 23.

Gonocrinus Eichwald, E., Zeitschr. für Natur u. Heilkunde der medicinischen Acadamie zu St. Petersburg, 1840.

Sococystis von Buch, L., Abhand. d. kgl. preuss. Acad. d. Wiss., Berlin, 1845.

The following is Bather's description of the genus *Echinoencrinites:* "Differs from the imagined archetype in the restriction of pectinirhombs to 1 and 5, 1 and 6, and 14 and 15, and in the apparent bisection of plate 23. The main grooves may support five brachioles, or only two, or may branch yet more; in any case the facets are always close around the mouth. Anal region often prominent. The plates usually have strong radiating folds, often crossed by finer concentric ridges."

ECHINOENCRINITES SENCKENBERGII von Meyer

Echinoencrinites senckenbergii von Meyer, Karstens Archiv für Naturlehre, 1826, Bd. VII. p. 185. Jaekel, Otto, Stammesgeschichte der Pelmatozoen, Berlin, 1899, p. 248, pl. 13, figs. 1, 2.

The writer considers published descriptions of this species inadequate and submits the following description based on the specimens in the Museum of Comparative Zoölogy:

Theca pear-shaped, expanded below to become, in some cases, more or less flat on the aboral side. The anus is between plates 7, 8, and 13 (after Bather's analysis) and is rounded in outline; in most cases the opening is projected downward at a definite angle from a triangular eminence on the three enclosing plates (the vertex of the triangle is directed upward).

The oral region is oval in outline and supports about ten arms; the lips are extended outward and upward or slightly overlap the theca.

The radiating folds are rounded to subangular and are continuous over the suture lines. The number of folds on a single plate varies from about 15 to 38, being less in the small specimens than in the large ones. Between the radial folds is a series of cross-ridges, varying in concentration, but in some cases there are as many as six folds to 2 mm. length. In a few cases these concentric folds are continuous over the radial folds; this phenomenon is present in a few specimens only. Most of the plate beaks are moderately projected; in some individuals they are more or less flattened.

One partially preserved stem shows about 25 columnals. Each proximal segment has a well-defined engirdling ridge about 1mm. in width. On the distal segments, comprising about one-third of the specimen at hand, engirdling ridges are present but they are flattened and widened and show well-developed transverse striae.

Measurements

	Small	Average	Large
Height	9 mm.	14 mm.	22 mm.
Width	7 mm.	11 mm.	18 mm.

Some fragmentary specimens indicate that a few individuals were larger than any of the above. The number of radial folds varies directly with size and there are all gradations. Variation in abundance of concentric folds appears to be quite independent of size. The diagrams (plate 1, figs. 4–8) show the development of the radial folds in a series of five specimens, ranging from the smallest to the largest in the collection. It must be kept in mind that a slight addition to the size of each individual plate can cause a great increase in the size of the theca; thus, the range in size of the plates is not great. Although there is an expected variation, in general it is observed that the folds increase in number in the larger specimens; moreover, the addition of new folds takes place at the suture angles. The resulting apparent variation in ornamentation, caused by the increase in total number of folds, is a direct function of size, and although apparently marked between large and small specimens, in the opinion of the writer does not indicate specific differences.

Formation and locality: Lamansky's zone $B_{III\alpha}$ or zone $B_{III\beta}$, opposite Iswos; at the mouth of the Sjas river; the mouth of the Lyna river; Iswos; Wassilkowa; and a quarry 3 miles east of Putilowa, U.S.S.R.

The plesiotypes are Mus. Comp. Zoöl. no. 3997.

ECHINOENCRINITES INTERLAEVIGATUS Jaekel

Echinoencrinites senckenbergii var. *interlaevigata* Jaekel, Stammesgeschichte der Pelmatozoen, Berlin, 1899, p. 249.

Jaekel separated the variety *interlaevigata* from *Echinoencrinites senckenbergii* von Meyer on the basis of the ornamentation being confined more or less to the plate centers, resulting in smooth plate borders. Several of the specimens of the Museum of Comparative Zoölogy show this characteristic; but gradations occur between the specimens showing complete ornamentation and those in which only the plate centers are ornamented. Although a complete series showing the development of this characteristic is not at hand, the indications are that such could be found.

It is important to note that the smooth plate borders are well-developed in the largest and are not indicated in the smallest specimens. One medium-sized specimen shows smooth plate borders on the plates of one side of the theca and fully ornamented ones on the other side. In other respects the specimens are like *E. senckenbergii.*

The development of such a character from the typical *E. senckenbergii* could, in the opinion of the writer, be due to three things: (1)

differential solution—by ground water, perhaps; (2) resorption of plate borders; or (3) old age. There is no indication that solution has taken place, since the plate umbos are plainly not affected; it is difficult to imagine such selective erosion as to produce the appearance shown by these specimens. Furthermore, the characteristic unevenness to be expected on the plate borders does not exist.

The smooth rims of the plates must, then, be due to organic causes. Shimer[1] has observed that flattening out of plications is an old age characteristic of brachiopods. Their former presence on the smooth senescent individual is indicated by growth lines. In *E. interlaevigatus* fine growth striations are abundant on most of the plate borders. Loss of skeletal features has been ascribed to a progressive loss of the power of growth which is characterized by Minot[2], in his work on guinea pigs, as "beginning almost immediately after birth." He raises the question "whether in all living things there is not a certain impulse given at the time of impregnation, and whether this impulse does not fade out so that from the very beginning of the new growth there occurs a dimunition in the rate of growth."

Loss of plications has also been observed by R. T. Jackson[3] in *Litorina littorea*, a gastropod which is at present abundant on the Atlantic coast: "While thus the increase in size becomes less and less for each succeeding growth period, a time is reached, varying with each individual, when another factor enters and actual shrinkage begins. The tendency of the soft parts of animals in old age to contract is familiar to us." This can explain alteration in hard parts, particularly in a form like a cystid. Shimer has shown that old age smoothness of the shell is caused directly by the contraction of the brachiopod mantle.

Jackson[4] has further shown that resorption is an important process in sea urchins. He points out that with an internal skeleton "there is a constant resorption within the plate concurrently with increase in external dimensions." Jackson also points out the role of variation in producing apparent differences: "A regressive variant is one that has attained full characters and then in later life has reverted to the youthful or primitive characters. . . . it is felt that we should be extremely cautious in assuming hybridity when the same results might be attained by variation."

---

[1] Shimer, H. W., Old Age in Brachiopods, Amer. Nat., 1906, **40**, pp. 95–122.

[2] Minot, C. S., Senescence and Rejuvenation, Jour. of Physiol., 1891, **12**, p. 151.

[3] Shimer, op. cit., p. 119.

[4] Jackson, R. T., Memoirs of the Boston Soc. of Nat. Hist., 1912, **7**, p. 18.

It is the opinion of the writer that the forms of *Echinoencrinites* here considered are regressive variants of *E. senckenbergii,* and that the variation is an old age character brought about possibly by resorption of the plate borders ; the fact that the smooth borders are in nearly every case confined to the large individuals is presented in support of this theory. Many of the plates of the specimens of this group have been distinctly displaced at the sutures, probably indicating a weakening of the body tissues in that area.

All the forms having well-developed smooth plate borders are placed in *E. interlaevigatus* for convenience.

Formation and locality: Lamansky's zone $B_{III\alpha}$ or $B_{III\beta}$, Iswos; opposite Iswos, and at the mouth of the Lyna river, U.S.S.R.

The plesiotypes are Mus. Comp. Zoöl, no. 3996.

ECHINOENCRINITES LAHUSENI Jaekel

Echinoencrinites lahuseni Jaekel, Stammesgeschichte der Pelmatozoen, Berlin, 1899, pp. 247–248, pl. 13, fig. 10.

In the specimens of this species there are observed similar gradations in number of radiating folds as in the writer's examples of *Echinoencrinites senckenbergii,* although the range in size is not as great. The largest is 18 mm. high and 12 mm. wide, whereas an average specimen is 14 by 12 mm. This form differs from *E. senckenbergii* mainly in the location and appearance of the anus, which is between plates 7, 8, 12, and 13. The prominence surrounding the anal opening is roughly square, is less distended than in *E. senckenbergii,* and is not deflected downward but faces directly to the side.

In some specimens there is a depressed area, with ornamentation less prominent at the plate borders than in the region of the umbo, but not actually smooth. The lips of the orifice do not lap over the theca quite to the extent shown in Jaekel's illustration.

Formation and locality. Lamansky's zone $B_{III\alpha}$ or $B_{III\beta}$, opposite Iswos; at Iswos, and Wassilkowa, U.S.S.R.

The plesiotypes are Mus. Comp. Zoöl. no. 3999.

ECHINOENCRINITES SPHEROIDALIS sp. nov.

Plate 1, fig. 2

Theca spherical, flattened below and above, expanded in the median circumference to become as wide as high. The anus is between plates

7, 8, and 13 and is rounded in outline. It projects downward at a slight angle from a roughly triangular eminence, and is only slightly distended from the theca. A comparatively narrow eminence extends from the anal opening to the beak of each of the enclosing plates.

The radiating folds are subrounded and extend over the suture lines. There are about 40 to 50 folds on each plate. Cross ridges are abundant between the folds, averaging three to 1mm. of length. The plate beaks are very slightly distended. Measurements: height, 18 mm; width, 18 mm.

This species is most closely related to *Echinoencrinites senckenbergii* von Meyer, but it differs in being as wide as high, in having more radial folds per unit size, in having the anus less projected from the theca, in having narrow, smooth eminences extending from the anus to the beaks of the enclosing plates, and in the comparative flatness of the plate beaks.

Formation and locality. Lamansky's zone $\mathrm{B}_{\mathrm{III}\alpha}$ or $\mathrm{B}_{\mathrm{III}\beta}$, Iswos, U.S.S.R.

The holotype is Mus. Comp. Zoöl. no. 3998.

ECHINOENCRINITES SIMPLICATUS sp. nov.

Plate 1, fig. 3

This species is like *Echinoencrinites lahuseni* in all respects except in plate ornamentation, which is more simplified. As in that species, there is one radial fold extending from the plate apex to the approximate center of each suture segment. These folds are distinct in their broadly rounded character and are much wider than in *E. lahuseni*, approaching 1mm. in width in the larger specimens. Very few auxiliary folds are developed, characteristically only one extending to each suture angle; at one of the suture angles in some of the plates (commonly plates 10, 11, 12, 13, and 14) there is a flat raised area. Transverse fila are present but are not as obvious as in *E. lahuseni*.

On one specimen there is a quadrangular area about ½ mm. in width on all plate borders, slightly insunken, which gives the effect of a geometric border. Most of the radiating folds are noticeably depressed in crossing this border.

The size of the specimens at hand varies as follows: height 9 to 17 mm., width 7 to 12 mm.

Formation and locality. Lamansky's zone $\mathrm{B}_{\mathrm{III}\alpha}$ or $\mathrm{B}_{\mathrm{III}\beta}$, Iswos, U.S.S.R.

The holotype is Mus. Comp. Zoöl. no. 3995.

Eutretocystis gen. nov.

There are three cystids in the collection which are like *Echinoencrinites* in all respects except in the development of an extra pectinirhomb on plates 10 and 15. It appears that the importance of the pectinirhombs has not been fully recognized by some workers. Bather, in his diagnosis of *Echinoencrinites* states definitely that pectinirhombs are restricted to plates 1 and 5, 1 and 6, and 14 and 15.

Jaekel places in *E. lahuseni* forms having pectinirhombs on plates 10 and 15. Since the rhombs are, according to Bather, "specialized outgrowths of the ambulacral system" and associated with respiration, it is the opinion of the writer that they are of generic importance.

Some of Jaekel's specimens referred to *E. lahuseni* should undoubtedly be referred to *Eutretocystis*. Only those specimens with three rhombs have been referred to *Echinoencrinites lahuseni* by the writer.

Genotype, *Eutretocystis similis* sp. nov.

Eutretocystis similis sp. nov.

Plate 1, fig. 1

The theca is pear-shaped, expanded below. The anus is between plates 7, 8, and 13 and is rounded in outline; the opening is projected slightly downward. It is in a comparatively smooth triangular eminence formed by the junction of the three enclosing plates; the vertex of the triangle is directed upward.

The oral region is oval in outline, apparently supporting ten or more arms. It does not overlap the theca.

Radiating folds on the plates are rounded to subrounded. There are 22 folds on the plate of a small specimen 11mm. high and 9 mm. wide, and 32 folds on the corresponding plate of a specimen 21mm. high and 14 mm. wide. Concentric cross-ridges are abundant between the folds, 2 to 3 occurring in each mm. Plate beaks are moderately projected.

Formation and locality. Lamansky's $B_{III\alpha}$ or $B_{III\beta}$, Iswos on the Walchow river, U.S.S.R.

The holotype is Mus. Comp. Zoöl. no. 4001.

EUTRETOCYSTIS ACUTIROSTRIS sp. nov.

Plate 1, fig. 10

The plate beaks rise sharply to a point which extends well away from the rest of the theca. The species is thus characterized by its angularity and in this way is distinguished from *Eutretocystis similis*.

Formation and locality. Lamansky's zone $B_{\text{III}\alpha}$, $B_{\text{III}\beta}$, Iswos, U.S.S.R.

The holotype is Mus. Comp. Zoöl. no. 4000.

Order DIPLOPORITA Zittel

Family PROTOCRINIDAE Bather

Genus PROTOCRINUS Eichwald

PROTOCRINUS FRAGUM Eichwald

Protocrinus fragum Eichwald, Lethaea Rossica, ou Paleontologie de la Russie, Band. I, Stuttgart, 1860, p. 621. Jaekel, Stammesgeschichte der Pelmatozoen, Berlin, 1899, p. 433.

Four specimens of *Protocrinus fragum* in the collection are rather poorly preserved, but one specimen shows the ambulacral grooves very well. They extend a little farther aborally than Jaekel's description indicates, to the upper edge of the lower radials. Most of the diplopores have been nearly or completely obliterated. At least two specimens are young animals, since they show a feeble stem development.

Formation and locality. Zone $B_{\text{III}\alpha}$ or $B_{\text{III}\beta}$ of Lamansky, mouth of the Lyna river; Hamantown village; and quarry west of Putilowa, U.S.S.R.

The plesiotypes are Mus. Comp. Zoöl. no. 4003.

EXPLANATION OF PLATE

PLATE

Fig. 1. *Eutretocystis similis* sp. nov. Lateral view showing pectinirhombs on plates 10 and 15, and 14 and 15. x 2.

Fig. 2. *Echinoencrinites spheroidalis* sp. nov. Lateral view showing the anal region. x 2.

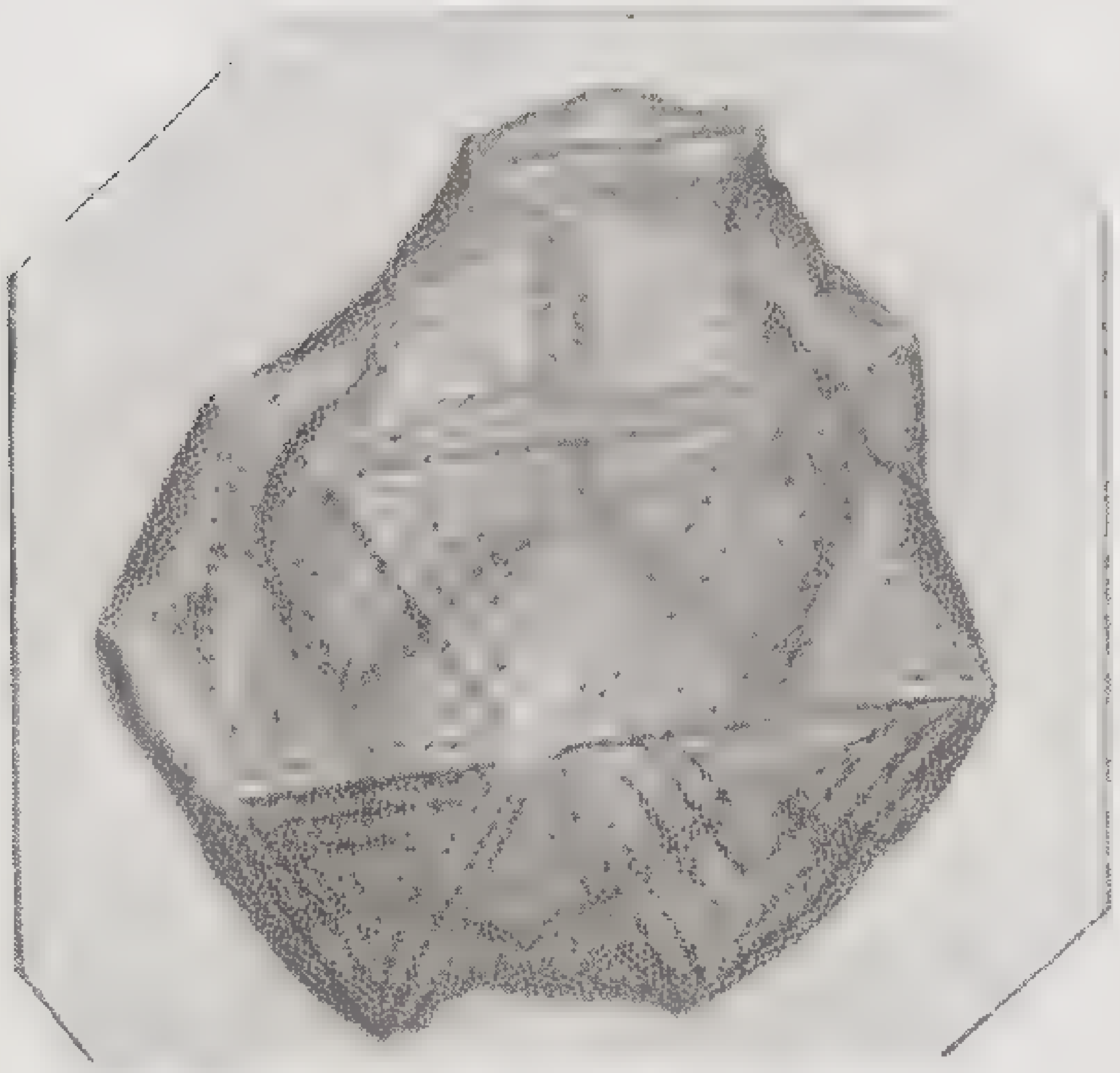
Fig. 3. *Echinoencrinites simplicatus* sp. nov. x 2.

Figs. 4 to 8. Showing the development of plate ornamentation in *Echinoencrinites senckenbergii* von Meyer. Figs. 4, 5, and 7 are diagrams of plate 12, 6 is plate 11, and 8 is plate 9 of successively larger specimens. x 2.

Fig. 9. *Rhipidocystis gigas* Jaekel. The anal pyramid. x 2.

Fig. 10. *Eutretocystis acutirostris* sp. nov. Lateral view showing pectinirhombs on plates 10 and 15, and 14 and 15. x 2.

Drawings by Mrs. Cecil Lalicker.



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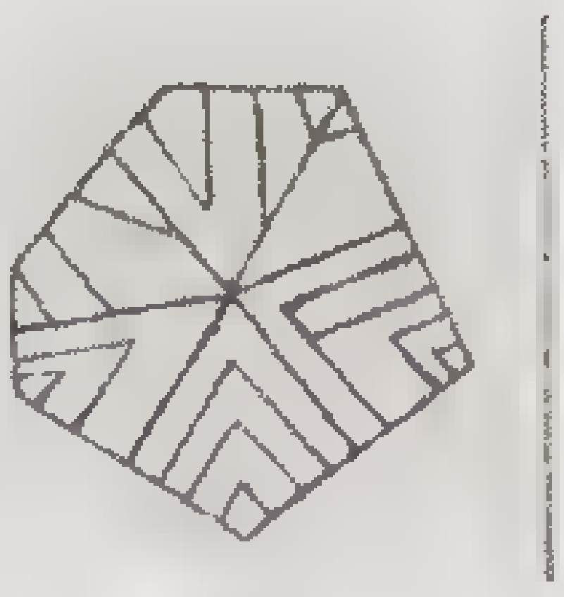

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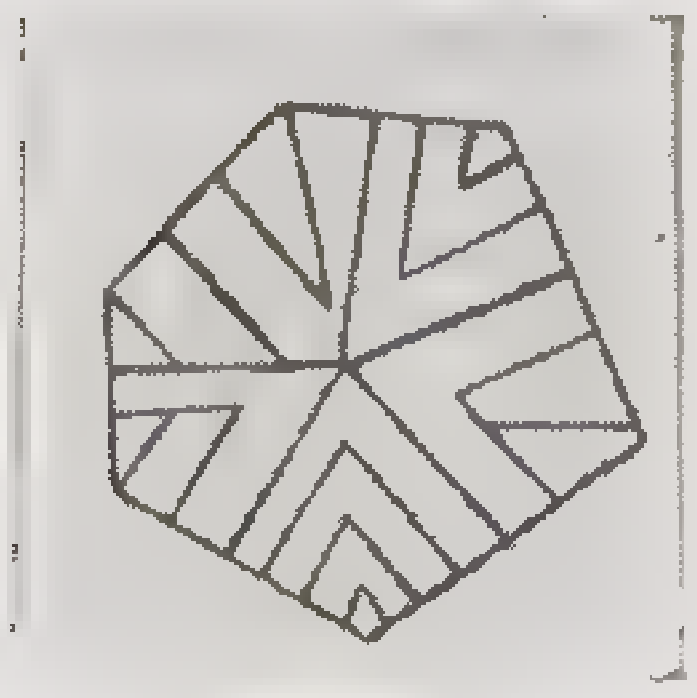

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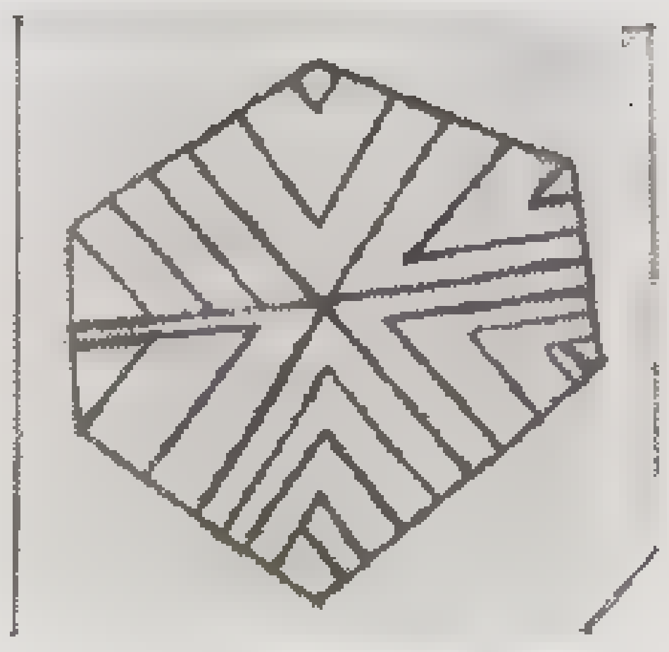

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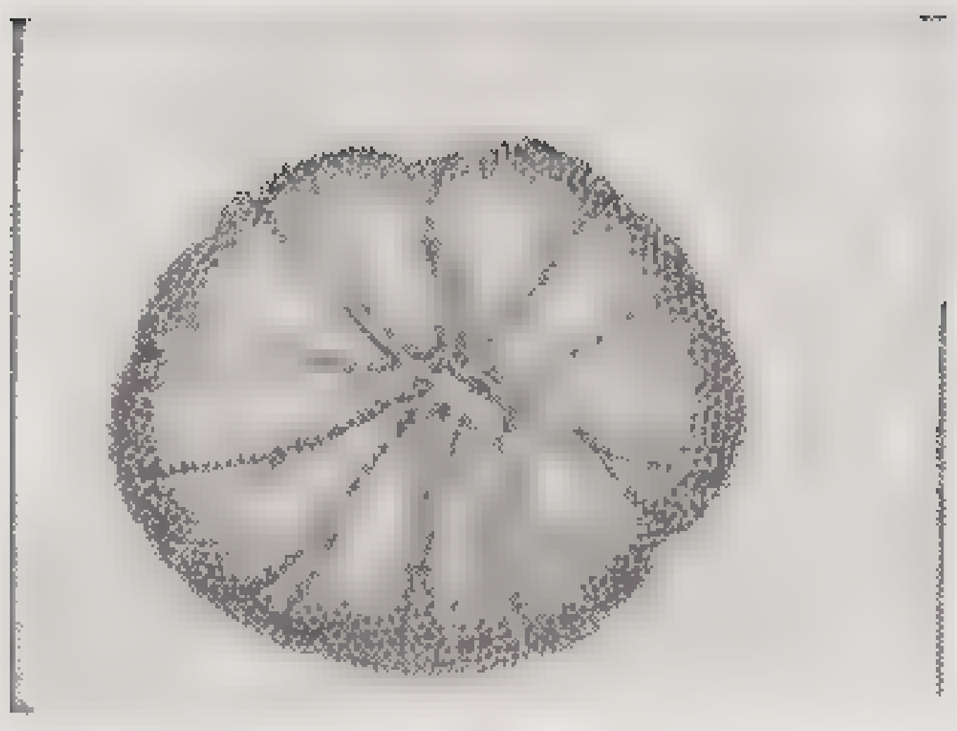

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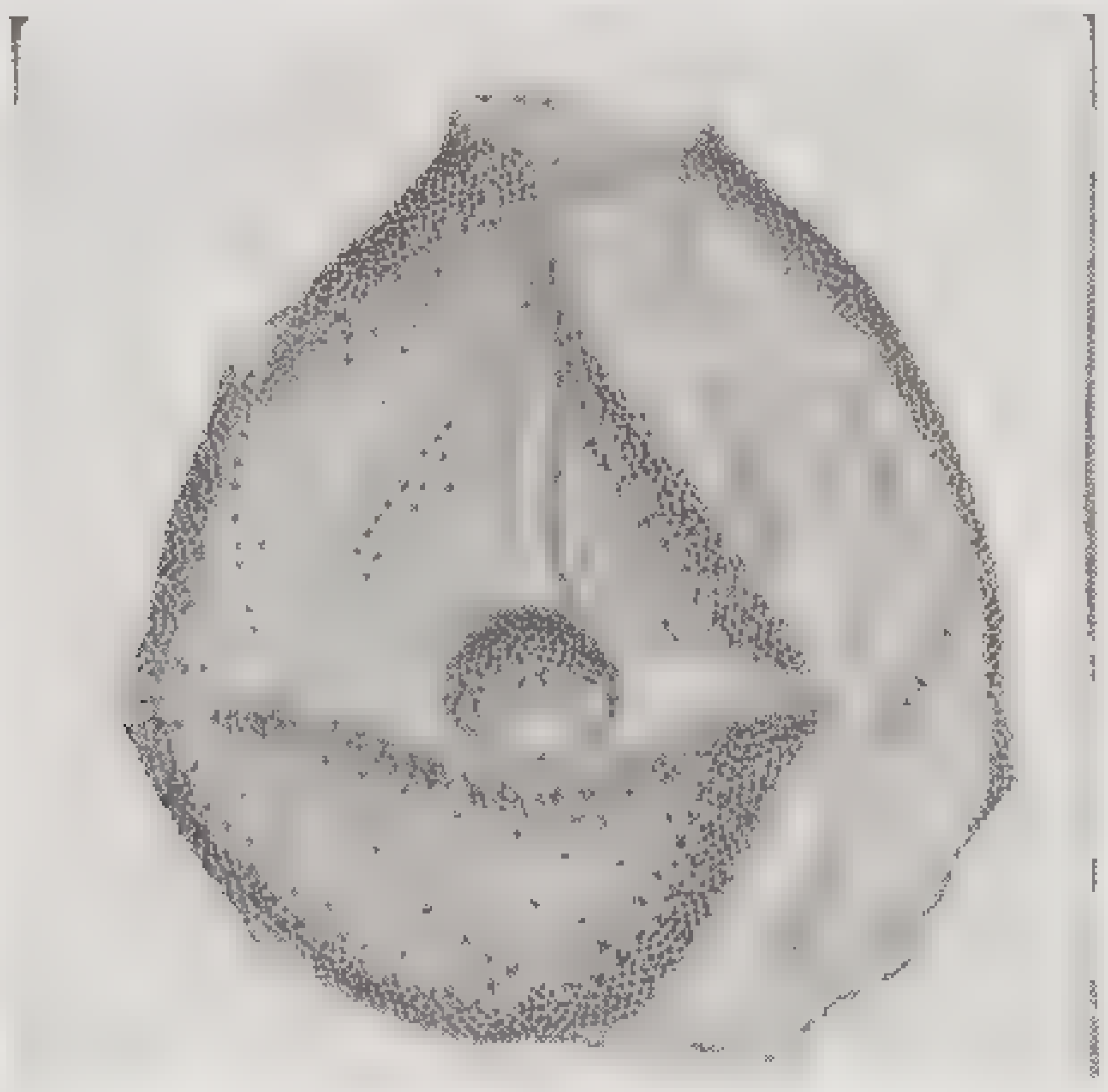

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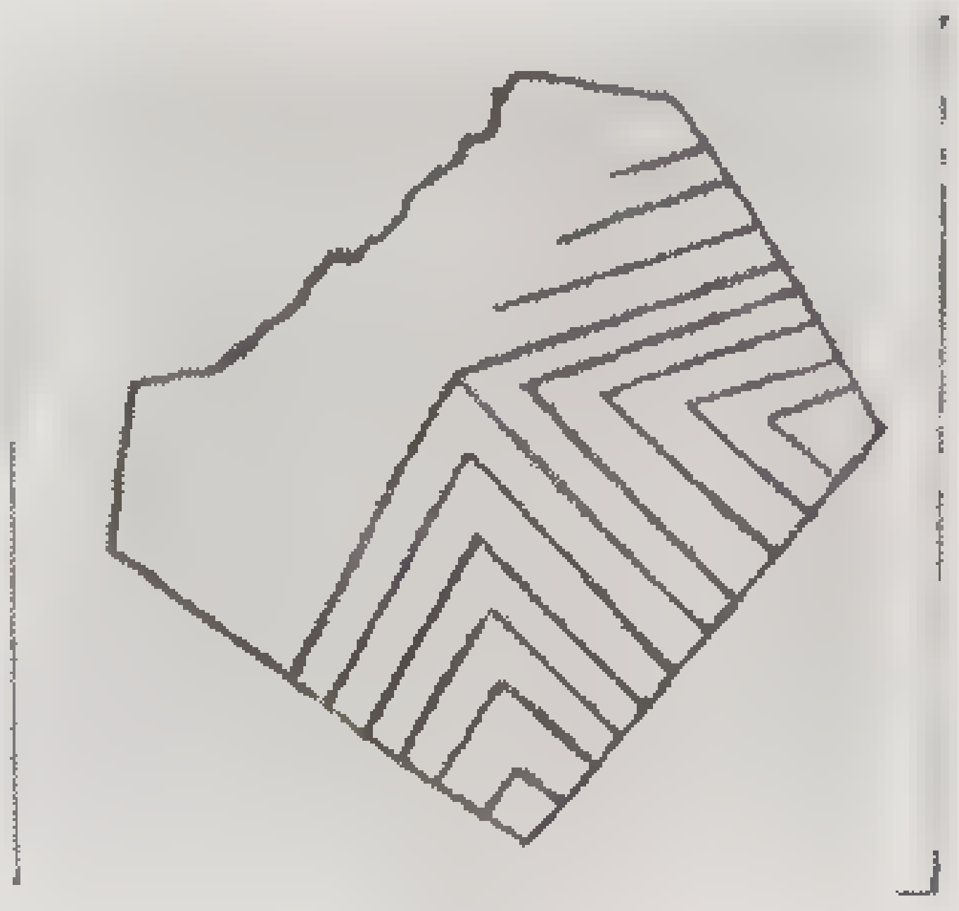

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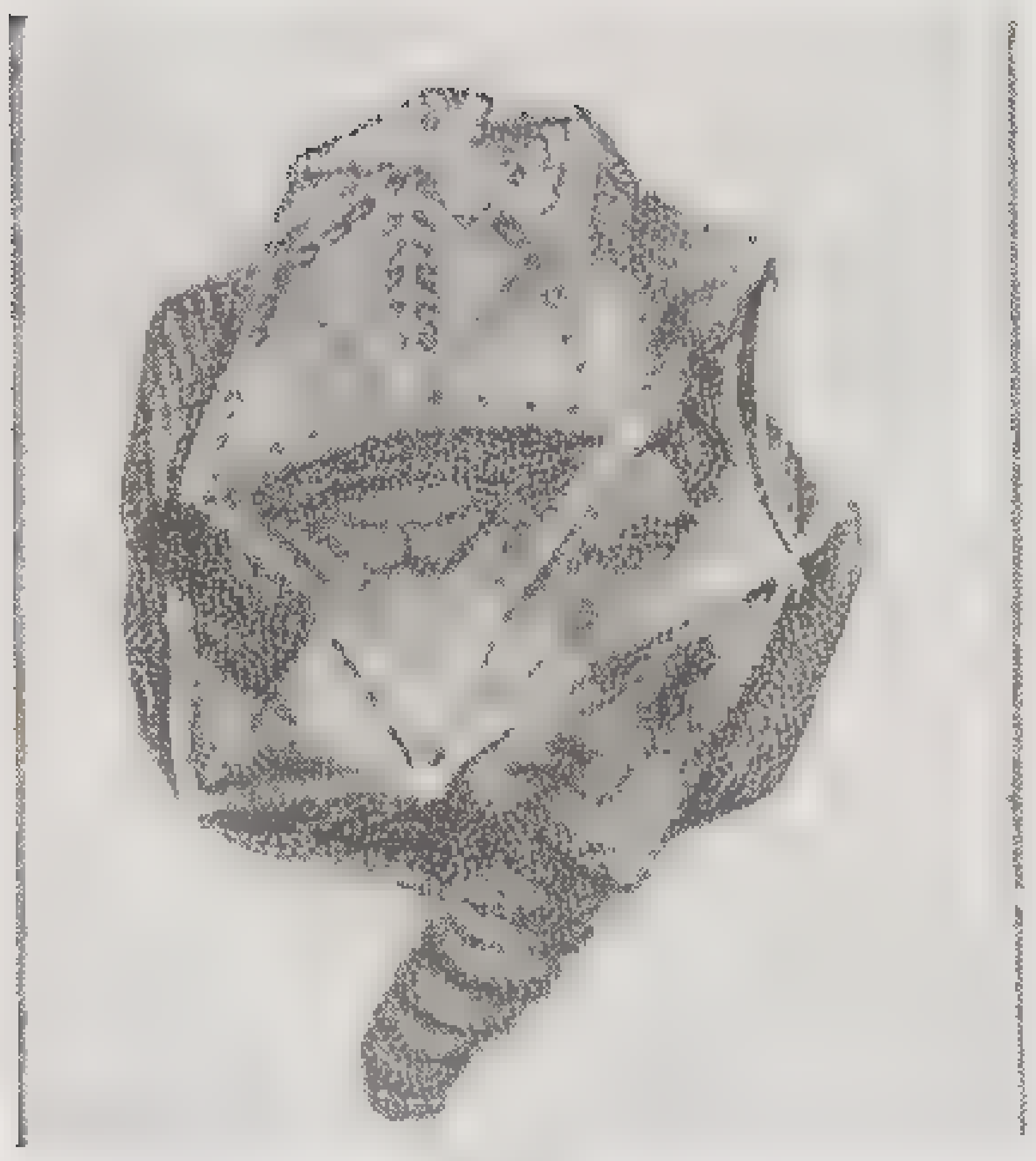

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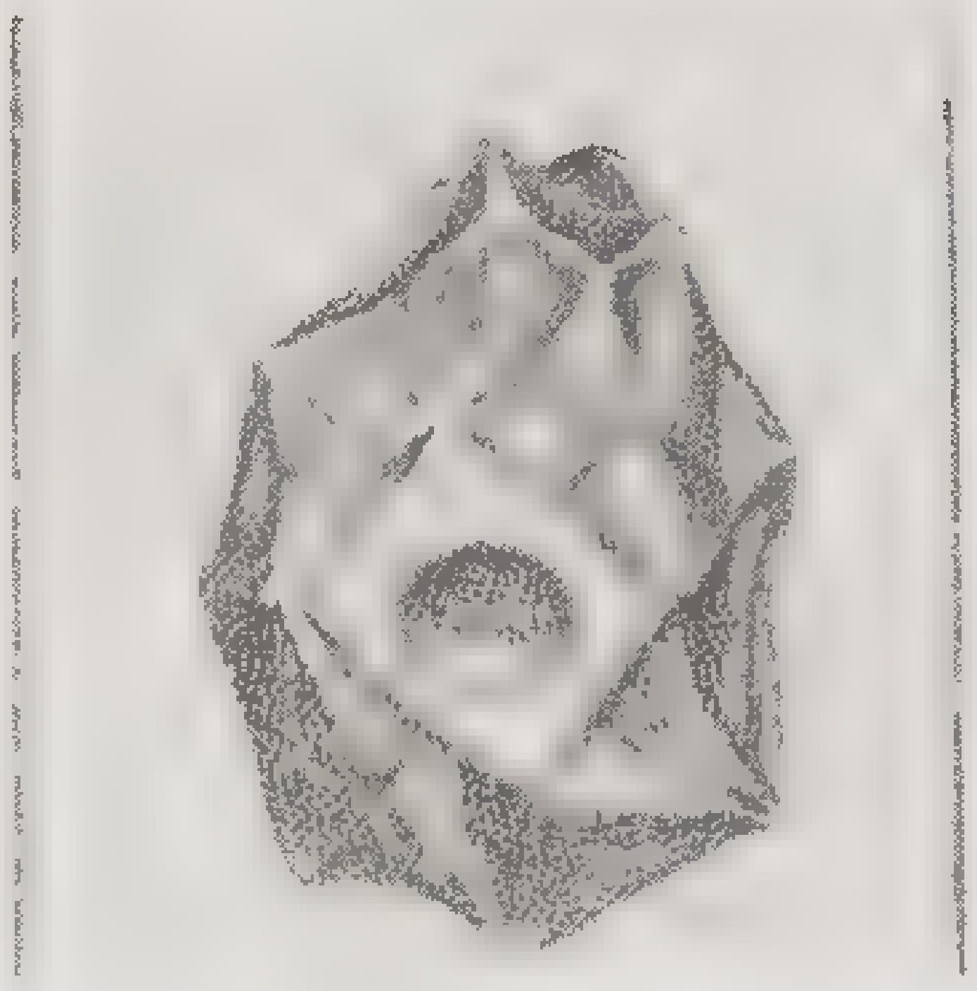

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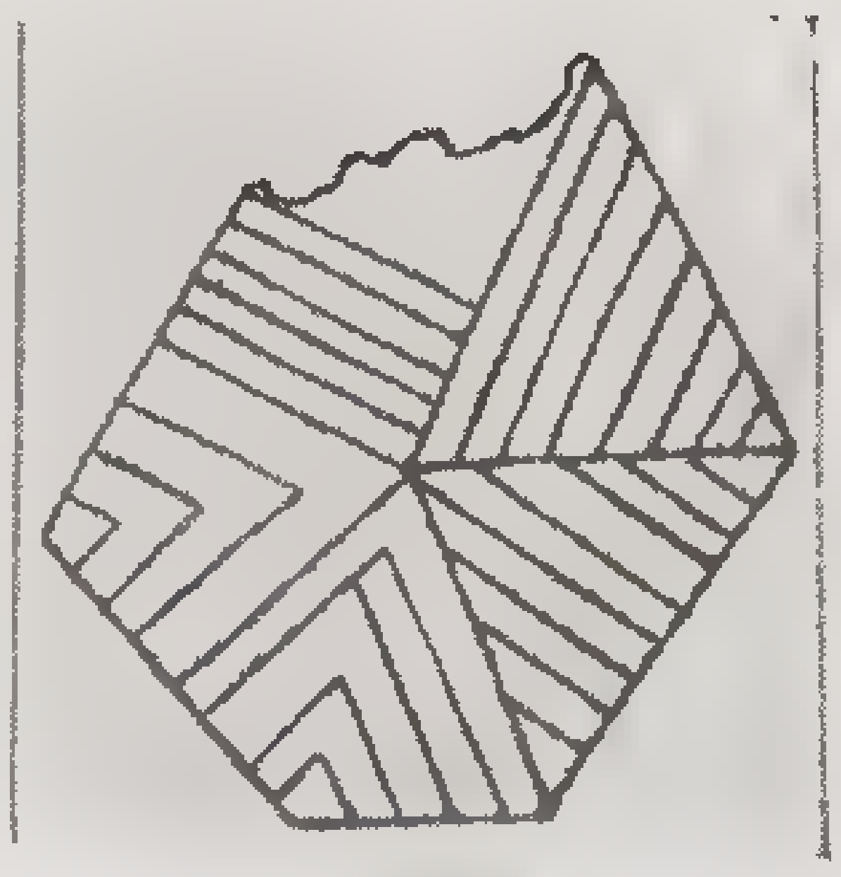

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JUL 26 1935

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LEANCHOILIA AND OTHER MID-CAMBRIAN ARTHROPODA

By Percy E. Raymond

CAMBRIDGE, MASS., U. S. A.
PRINTED FOR THE MUSEUM
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LEANCHOILIA AND OTHER MID-CAMBRIAN ARTHROPODA

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No. 6. — *Leanchoilia and other Mid-Cambrian Arthropoda*

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Leanchoilia superlata was described by Dr. Walcott (1912, p. 170, pl. 31, fig. 6) at a time when he had only one incomplete specimen. Although he collected others later, he published no further description of this species, but (1931, p. 8, pl. 12, pl. 13, fig. 2, pl. 14, fig. 4, 5.) figured some excellent specimens.

Several more or less complete individuals were collected by Mr. W. E. Schevill in the summer of 1930 while a party from the Museum of Comparative Zoölogy[1] was working in the Middle Cambrian on Burgess Pass. Rather to our surprise, we did not find any specimens in Dr. Walcott's old quarry, all which we obtained being derived from a layer some seventy feet further up the mountain side.

In addition to our own specimens, I have been able to study those in the U. S. National Museum, through the kindness of Dr. C. E. Resser, and one in the Peter Redpath Museum, thanks to Dr. T. H. Clark.

Leanchoilia was referred by Walcott to the order Anostraca under the subclass Branchiopoda, and included with Opabinia in the family Opabinidae.

Fedotov (1925, p. 385) doubted if Leanchoilia were really a branchiopod, stating that its general habitus and appendages suggested relationship to the amphipods. He further questioned if there was any close relationship to Opabinia.

Henriksen (1928, p. 7) was able to study two complete individuals of Leanchoilia, and found that there were ten segments in the trunk, behind which was a long telson bearing a fringe of setae. He considered the evidence to indicate that the animal is a merostrome, and that the species is identical with *Emeraldella micrura* Walcott.

Hutchinson (1930, p. 2) did not discuss Leanchoilia, merely noting with approval that Henriksen had assigned it to the Merostomata.

Description of the test

The general form of the skeleton is best shown by specimen M.C.Z. 1842, an individual which is flattened dorso-ventrally instead of laterally, as are most of the others. As preserved on the rock, the test is seen from the inside. The head, body, anterior part of the telson, and some appendages are preserved.

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[1] The material upon which this paper is based was collected with the aid of the income of the William and Adelaide Barbour Fund.

The head as flattened is roughly triangular, about as broad as long. At the anterior end it is extended into a short rostrum. There is no visible opening of any kind through the test of the head, and no notch in the margin for a pedunculate eye. The body consists of ten segments of approximately equal length. As flattened, the width of the body increases up to the eighth segment; the lateral portions of the ninth and tenth turn backward and inward toward the telson.

Throughout the length there is a narrow axial lobe which does not exceed one fifth the total width. It is limited by a pair of very narrow longitudinal furrows on the inside of the test, which must have found expression externally as corresponding linear ridges.

Specimen M.C.Z. 1846 B represents an individual in the more common state of preservation, flattened from the side. The anterior end of the head is a pointed rostrum, turned upward in this as in other specimens similarly compressed. The body has ten segments, behind the last of which is a telson. The back of the head and of each segment projects high above the front of the adjacent segment, giving the impression that there was a sort of crest along the median line. Closer study shows, however, that several of these angular peaks are double, the shell having broken along the back when it was flattened. A faint longitudinal line indicates the lateral border of the axial lobe. The pleural portions of the segments extend downward and slightly backward, each ending in a recurved point.

The Appendages

The outstanding characteristic of Leanchoilia is the presence of a pair of huge tripartite appendages on the head. These are well preserved in specimen M.C.Z. 1843, which retains an almost complete one belonging to the right side, and a less perfect one on the left.

The innermost segment is not completely exposed on either, but is short, abruptly curved, forming a sort of peduncle by which the appendage is suspended beneath the head. Because of the curvature, the proximal end is nearly parallel to the axis of the appendage, suggesting that it was the locus of attachment, but this has not been definitely verified.

The second segment is stout, much wider at the outer than at the inner end. The profile of the lower margin is strongly convex, continuing the curvature of the proximal segment. At its distal end it supports two branches, an outer double one, and an inner, stouter, single ramus. The latter consists of two segments, the first short and stout, the second elongate, tapering outward nearly to the end, where it is somewhat enlarged. There are three terminal spines, apparently movable, since they are not in the same position in all specimens. One of these spines is nearly straight, very long, and finger-like. The other two are shorter, somewhat stouter, and gently curved.

The appendage being described is that of the right side, and is flattened in such a way as to show its inner face. In this position, the first of the segments of the uniramous branch has so broad an articulation with the second segment of the appendage that it overlaps a large part of the articulatory end of the double branch. It is therefore on the inner side of the appendage, so is an endopodite.

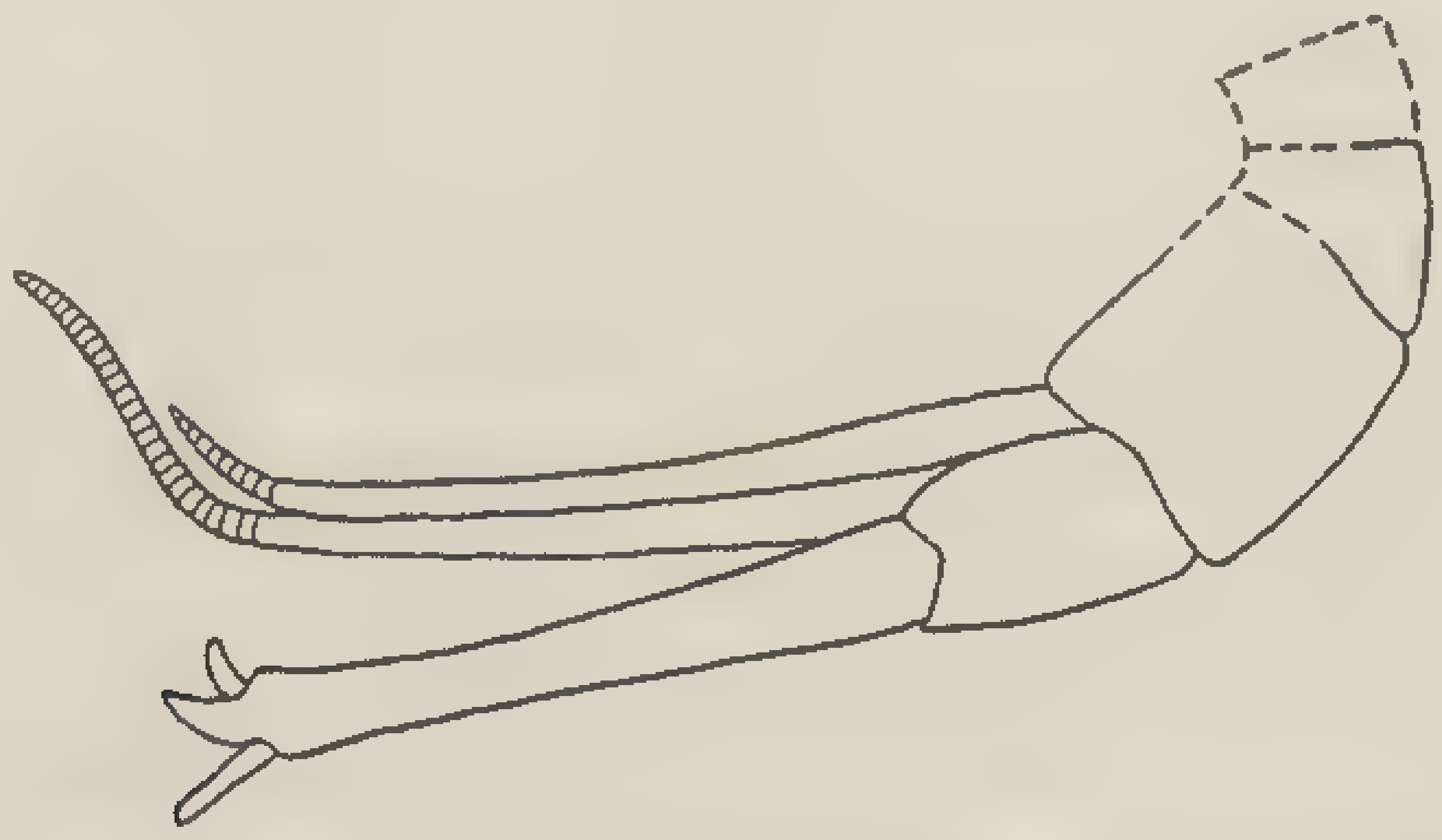

Fig. 1. The right "great appendage" of specimen M.C.Z. 1843, showing the segmented protopodite, the bifurcated exopodite and the spine-bearing endopodite. x2.

The exopodite consists of two long slender branches which appear to be entirely independent of one another. Each consists of a very long slender proximal shaft, at the end of which is a lash made up of short segments, each about half as long as wide. The flexible portion appears to be about half as long as the proximal segment. One of the branches is dorsad in its position in regard to the other. The upper one articulates with the upper part of the distal end of the large second segment of the appendage. The lower one articulates independently with the end of the same segment, its proximal end being below that of the upper branch and outside the first segment of the endopodite. This is best shown on the left large appendage of specimen M.C.Z. 1843.

If we use the terminology commonly employed in describing Recent crustaceans, the segment bearing the endopodite is the basipodite, and the short curved one inside it, the coxopodite. Together they make up the protopodite.

Measurements: The following measurements of the parts of the appendages on the right side of specimen M.C.Z. 1843 will suggest the relative proportions. The coxopodite is 4 mm. long on the median line, and 2.5 mm. wide at the distal end. The basipodite is 7 mm. long, 5 mm. wide at the distal end. Total length of endopodite without spines, 17.25 mm.; length of inner segment, 4.25 mm., width 3 mm.; length of outer segment, 13 mm., width at base, 2 mm., at narrowest part, 1.25 mm. Length of first segment of dorsal branch of exopodite, 16 mm., width at proximal end, 1.5 mm., at distal end, 0.75 mm. Length of first segment of ventral branch of exopodite, 17 mm.; length of segmented portion, 6 mm.

Other appendages of the head

All other appendages of the head are small, and specimens so far found do not permit their proper description. It is as yet impossible to determine how many there are, or even their exact nature. Specimen M.C.Z. 1843 shows faint traces of appendages which are pressed upon the proximal segments of the large ones just described. One pair of these may be uniramous tactile organs, but they are so far from their natural position that one can not be sure. The better preserved of the two is 8.5 mm. long. It lies, with the apex turned backward, across the basipodites of both the large appendages. It is nearly straight, but shows traces of segmentation. Its mate is curved. Only a small portion is visible, as it disappears forward beneath other structures. Although specimen M.C.Z. 1844 has appendages which may be like these, they are too poorly preserved to be satisfactory.

The other cephalic appendages of specimen M.C.Z. 1843 are too fragmentary to be of any value.

Specimen M.C.Z. 1842 shows a pair of appendages in front of the large tactile organs, but whether they belong in front of them is doubtful. They are obviously displaced, turned end for end. One lies just at the margin of the head, which is flattened dorso-ventrally, the specimen revealing the lower side. This appendage belongs to the right side. The anterior end is at the base of the rostrum, the posterior one just in front of the protopodite of the large tactile organ. The appendage is about two and a half times as long as wide, approximately parallel-sided. The posterior end appears to have three tooth-like processes, the inner one reinforced by a wide lateral addition to the shaft. The corresponding limb of the left side is pressed against the inside of the head, so that it is difficult to distinguish its outline. That it can be seen at all is due to the fact that these appendages have weathered to a reddish rust, whereas the greater part of the test is yellow. It seems to be somewhat longer and more slender than its companion, but the posterior end shows a similar arrangement of the tooth-like processes. The general form of these two appendages suggests that they are mandibles. It must, however, be admitted that they are not satisfactorily preserved. No trace of them has yet been observed on other specimens.

The only other appendages yet seen on the head are fimbriated exopodites of the same general type as those described below as occurring on the thoracic segments. Specimen M.C.Z. 1842 has one extending out from about the middle of the left side of the head, another, but faintly visible, pressed upon the inside of the test in advance of the proximal end of the right "great" appendage, and another pair flattened against the inside of the posterior part of the head shield.

Specimen M.C.Z. 1846 B shows parts of two exopodites underneath the head, one of them very clearly preserved. Specimen M.C.Z. 1845 has a row of eleven exopodites on one side. Since there are only ten segments in the trunk, at least one of the appendages must belong to the head, which is not preserved on this individual. The arrangement of the exopodites indicates that at least ten were thoracic appendages. Specimen M.C.Z. 1844 also shows an exopodite belonging to the head. All these cephalic exopodites are broad, nearly circular in outline, differing in this respect from the narrower ones on the segments of the trunk.

Appendages on the trunk

Specimen M.C.Z. 1846 B is complete, and crushed from the side. It retains the "great appendages" and the telson, so there can be no question as to the identification. The exopodites extend far below the test on the left side, their outer ends being beautifully preserved. Ten are clearly visible, somewhat overlapping one another, and not all in exactly the same plane. Since the number corresponds to the number of thoracic segments, it is probable that they all belong to the same side. This deduction is the more reasonable because the animal is flattened in such a way that it shows somewhat more than half the shell, hence the appendages of the right side must be entirely beneath the test.

Each exopodite has a long, broad, blade-like shaft, with close-set finger-like "filaments" projecting from the distal and posterior margins. Except that it is not made up of two segments, and that filaments are present on the end, the exopodite is very like that of Neolenus.

There seems to be but little difference between those of the anterior and posterior segments of the trunk.

To give some idea of the proportions, it may be stated that the exopodite of the third segment projects 15 mm. beyond the test, is 5 mm. wide 6 mm. from the outer end, and the longest filaments on the posterior margin are 4 mm. long. In a linear distance of 4 mm. along the posterior margin there are nine filaments. The distal portion of the exopodite of the first segment is especially well preserved. The outer end is nearly semicircular in outline and carries eleven filaments, the longest 3 mm. long.

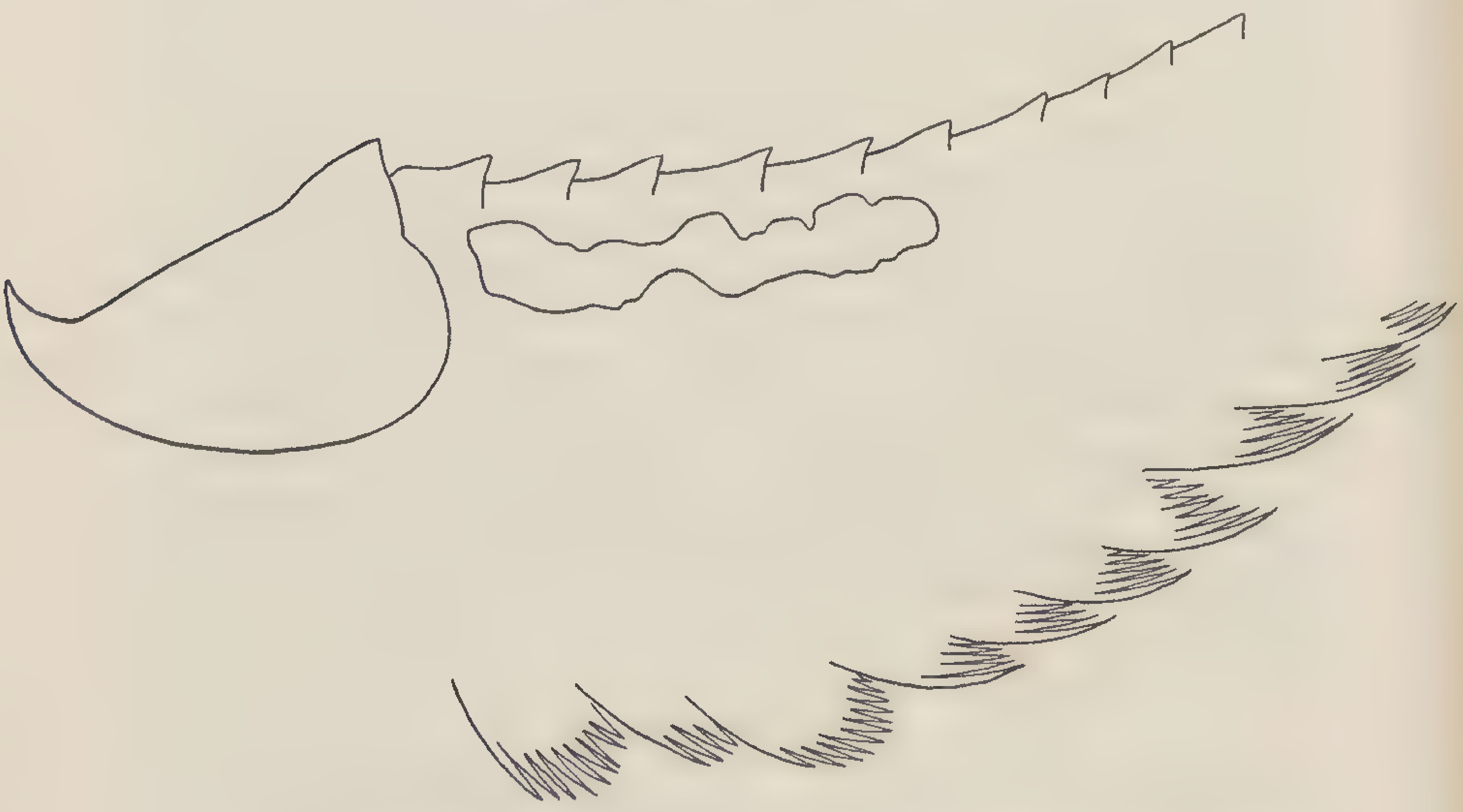

Fig. 2. Outline of specimen M.C.Z. 1846 B, showing the tips of the thoracic exopodites. The irregular object beneath the dorsal spines represents the filling of the alimentary canal. x1½.

Specimen M.C.Z. 1845 is flattened dorso-ventrally, preserving the telson and parts of all the segments of the body. Alongside it are eleven exopodites, rather evenly spread, apparently remaining opposite the segments to which they belong. These exopodites expose their inner faces, which are somewhat different from the outer ones shown so well by M.C.Z. 1846. Although no individual appendage is absolutely complete, two or three of the anterior ones are almost so. Two of them, fortunately, show the articulatory ends. The blade has a broad articulation with a proximal segment, which is short, nearly oval in outline as flattened, drawn out mesially into a short, narrow projection. There is no indication of how this protopodite was attached to the ventral membrane. The spinelike inner end was probably not connected with the body, but was free to act as an endobase or gnathobase. The blade-like portion appears narrower when seen from the inside than from the outside, and its posterior margin is less distinct. This seems to be due to the attachment of the filaments to the inner face some distance in front of the posterior margin of the blade. There is no distinct line along which they are attached, but they may be seen pressed against the inside of about the posterior half of the blade.

One exopodite looks as though it were made up of two parts, a short inner and a longer outer one. Since this condition is not seen in any other, it is probably due to an accidental displacement of the filaments.

The posterior exopodites of this specimen are distinctly shorter than the anterior ones, as would be expected.

Endopodites were certainly present on the trunk of Leanchoilia, but the specimens now at hand give little information as to their form, and no suggestion as to their number.

Specimen M.C.Z. 1843 shows the distal end of one behind the left "great appendage." It has a long, slender terminal spine with two subordinate ones. Behind it are tips of two or three more appendages which are probably endopodites, for they end in spines which are longer and fewer in number than the filaments on the exopodites.

Specimen M.C.Z. 1846 B shows the distal end of a slender endopodite just in front of the first exopodite of the trunk. It is, however, too poorly preserved to be of any value.

Alimentary tract

Several specimens show in some part the filling of the alimentary canal. It is most conspicuous in specimens M.C.Z. 1846 A and B, which are part and counterpart. This animal died with, perhaps because of, a great mass of food in that part of the canal between the posterior margin of the head and the ninth segment. The alimentary tube was segmented, constructed at the boundaries between the segments of the trunk. The material within the tube consists of a black carbonaceous substance in oval masses of considerable thickness. One of the well preserved pieces, filling the enlargement in a single segment, is 4 mm. long, 3 mm. wide, and about 1 mm. in thickness.

The surface is transversely laminated, indicating that it had been subjected to the pressure of annular muscles in the walls of the alimentary canal.

Telson

The telson is elongate, tapering gradually to an acute point. In the Peter Redpath Museum at McGill University there is a very good specimen, flattened from above, about 8.5 mm. long and 3 mm. wide at the anterior end. The surface is featureless, without ornamentation or median ridge. Tapering spines line both the sides, appearing to emerge from beneath the telson. They are directed backward, their axes parallel to one another, at a low angle, about 30°, with the axis of the telson.

Another isolated telson of about the same size in the Museum of Comparative Zoölogy, appears to show the lower surface. The spines are directed backward at a still lower angle with the axis than those of the McGill specimen. They appear to be inserted in sockets, in a fashion similar to the movable spines on the margins of the metasoma of Limulus. A darker band about the base of each spine indicates the thickening of the chitin bordering the socket.

The telson of still another much distorted and imperfect individual supports the contention that the lateral spines are inserted in sockets, for, as flattened, one side is scalloped, the proximal ends of the spines being in the recesses.

The telsons of the individuals which have been laterally compressed are too poorly preserved to be of any service.

All of the specimens mentioned above show a small ventral underturning of the margins of the shell, a sort of doublure; only at the posterior end is the ventral side completely covered. The telson was not therefore a mere spine-like process, as is that of Limulus.

Reconstruction

Leanchoilia appears to have been a short, laterally compressed, round-backed animal with a sharp rostrum and narrow elongate telson. The head was covered by a fold of shell, the sides of which were progressively deeper toward the back, whereas the anterior end was an uptilted spine. The ten segments of the trunk were provided with deep lateral extensions, protecting the body and appendages. Since there is no trace of the presence of sternites, the under surface must have been a thin membrane, as in the trilobites. The appendages were attached to this membrane, and not, with the possible exception of the "great appendages" of the head, to the test.

Walcott states that "The large opening on the side of the head indicates a large pedunculated eye comparable to that of *Opabinia regalis.*" As a matter of fact, there is no opening on the side of the head, even in the holotype. This specimen shows a reniform depression which occupies a large area on the side of the head. The position and shape are correctly shown in Walcott's figure (1912, pl. 31, fig. 6). Similar areas are to be seen on two other specimens (one numbered 239 N on green label) in Walcott's collection. Although no lenses are visible on any of these, it seems likely that the reniform areas are the remains of very large sessile compound eyes. If so, Leanchoilia was probably an inhabitant of rather deep water, in the zone of feeble light.

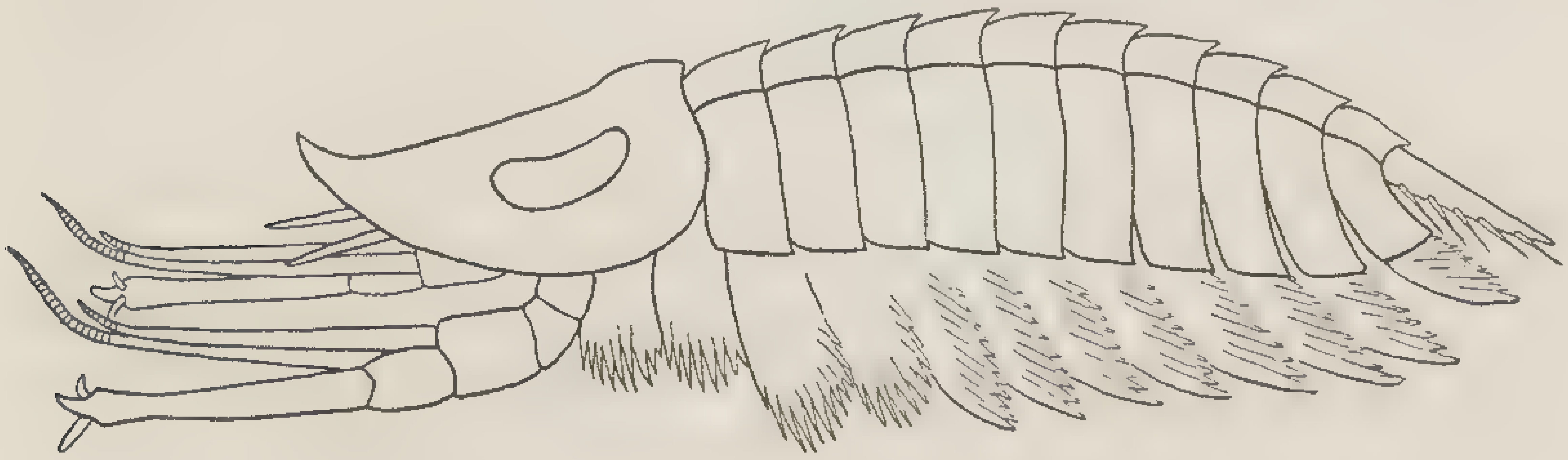

FIG. 3. A restoration of *Leanchoilia superlata* Walcott, about one half larger than the average specimen.

The probability that the animal had sessile eyes is increased by the fact that no indications of stalked eyes exist. Not only is none preserved on any specimen, but there are no notches in the margin of the head-shield, or other evidences of their presence.

The only satisfactorily known organs of the head are the "great appendages," already described. These were held beneath the head in a horizontal position by the curved protopodites. Although no proof remains, they were probably the second appendages, the antennae. There is some evidence that there was a pair of uniramous antennules in front of them. The mandibles are known only from the inner portions, the gnathobases, which are armed with denticulations at the inner ends. That each had an exopodite is probable, for impressions of such are found ahead of the bases of the "great appendages" on specimen M.C.Z. 1842. These must have belonged to appendages far forward, and hence probably to the mandibles, which are the first appendages which would be expected to show the flattened setiferous type of exopodite. Slender endopodites were probably present behind the mandibles, for indications of such are seen on specimen M.C.Z. 1843. I believe the head had five pairs of appendages, although there is no satisfactory indication of more than three. That at least two of the pairs had large, somewhat fan-like, setiferous exopodites is, however, clear.

Each segment of the trunk bears an appendage with a short coxopodite, probably attached along its upper surface to the ventral membrane, in such a way as to leave the inner end free to serve as a gnathobase. The long blade-like exopodite is attached to the outer end of the coxopodite.

There is no very definite evidence of endopodites, although such organs were presumably present. If so, they were slender, segmented branches such as are suggested by specimen M.C.Z. 1843.

The telson was spine-shaped, but with a narrow doublure instead of a complete ventral covering. It bore no appendages, but several pairs of slender spines were articulated in sockets on its margins.

Relationships to Other Arthropods

Although the structure of Leanchoilia is not fully known, still it obviously, like all the other arthropods from the Burgess shale, has the trilobitan type of appendages, hence can not be referred directly to any of the modern orders of Arthropoda. The antennae are curiously like those of certain Decapoda, a fact of no significance as an indication of relationship. Suggestions as to possible connections with modern animals can be obtained only by reviewing again the whole arthropod fauna of the Burgess shale.

Walcott recognized, among the fossils retaining appendages, the following:-

Merostomata.
  Limulava.—Sidneyia.
  Aglaspina.—Molaria, Habelia, Emeraldella.
Trilobita.—Marrella, Nathorstia, Neolenus.
Branchiopoda.
  Anostraca.—Opabinia, Leanchoilia, Yohoia, Bidentia.
  Notostraca.—Naraoia, Burgessia, Anomalocaris, Waptia.
Malacostraca.
  Hymenocarina.—Hymenocaris.

Contrary to the usual custom, Walcott included the Merostomata among the Crustacea, hence, although the Limulava resemble eurypterids and the Aglaspina suggest relationship with the xiphosurans, no member of the fauna was described as an arachnid.

Reviewing these arthropods as best I could from the published descriptions and figures, I (1920, p. 106 et seq.) agreed with Walcott that all were crustaceans, and, to avoid the implications of the term Merostomata, removed the Limulava and Aglaspina to new subclasses. I pointed out that, so far as could be determined, all of these animals had tactile antennules, and all had at least some exopodites and endopodites of the trilobitan type. My scheme was, then, only slightly different from that of Walcott. I recognized:

Trilobita. Naraoia, Nathorstia (=Neolenus).
Branchiopoda.
  Anostraca.—Opabinia.
  Notostraca.—Burgessia, Waptia, Yohoia.
Haplopoda (a new subclass).
  Marrellina.—Marrella.
  Aglaspina.—Molaria, Habelia.
Xenopoda (a new subclass).
  Limulava.—Sidneyia, Emeraldella.
Malacostraca.
  Hymenocarina.—Hymenocaris

Fedotov (1924, p. 384) reviewed the papers of both Walcott and myself, reaching conclusions which in some respects differ from both. His views may be summarized as follows:

Branchiopoda.
  Anostraca.—Opabinia, Yohoia.
  Notostraca.—Burgessia.
  Conchostraca or Cladocera.—Marrella.
Branchiopoda or Ostracoda—Hymenocaris.
Malacostraca.
  Leptostraca.—Waptia.
  Possibly related to Isopoda.—Molaria, Habelia, Emeraldella.
  Possibly related to Amphipoda.—Leanchoilia.
Merostomata (Arachnida).
  Sidneyia.

Henriksen (1928, pp. 1–20) discussed Walcott's papers, with the advantage of having specimens for comparison. He reached the following conclusions:

Branchiopoda.
  Anostraca.—Opabinia, Bidentia.

Near Notostraca.—Marrella, Burgessia, Yohoia.
Malacostraca.
Leptostraca.—Waptia, Hymenocaris, Carnarvonia, Anomalocaris.
Merostomata.
Leanchoilia.
Aglaspina.—Molaria, Habelia, Emeraldella.
Xiphosura.—Naraoia.

Sidneyia was placed in a group sharing the characteristics of the Trilobita, Branchiopoda and Merostomata, but not assigned to any subclass.

Walcott (1931) in a posthumous paper, edited by C. E. Resser, has supplied new figures and restorations of Naraoia, Marrella, Burgessia, Leanchoilia, and Waptia. All of these corroborate my opinion of 1920 that the appendages are essentially like those of trilobites. Störmer (1933) has recently done a signal service in pointing out that the trilobite exopodite is a very distinctive thing, having a structure unlike that of any crustacean and paralleled only in Limulus. The exopodites of trilobites are fringed with long, blade-like filaments, which differ entirely from the setae of crustaceans. The exopodites of the other Mid-Cambrian arthropods, so far as known, are of this same type, hence Störmer has questioned whether they are not, after all, arachnids.

It seems to me that the outstanding characteristics of Crustacea are the presence of tactile organs as the first pair of appendages, and the rather universal evidence of the actual or former presence of biramous limbs. That filamentiferous exopodites should be found only in the trilobites, other Mid-Cambrian arthropods, and Limulus, seems merely to strengthen the belief that the latter animal is descended from some group of the former, retaining the primitive type of gill. The trilobitan exopodite was not a very efficient sort of gill. Its chitinous covering was apparently relatively thick, reducing the effectiveness of its respiratory function. It was too clumsy to aid in swimming; in fact it is probable that the better the trilobite swam, the more closely it kept its exopodites folded across the ventral membrane. Hence as better methods of respiration evolved in the Crustacea, exopodites degenerated till only a part of the primitive shaft remained. This has been lost, or has become variously modified in different groups. The xiphosurans, on the other hand, have retained the general shape and some habits of the majority of the trilobites. Bottom dwellers, and relatively poor swimmers, they have retained, although in a very considerably modified form, the ancient type of gill.

The Mid-Cambrian Branchiopoda

In my discussion in 1920 of the fossils described by Walcott from Burgess Pass, I took the position that, for purposes of classification, the general habitus was more important than the nature of the appendages. I therefore followed Walcott in assigning Burgessia, Waptia, Yohoia, and Opabinia to the Branchiopoda. The general form of some of these animals is so similar to that of certain modern branchiopods as to suggest that they were really ancestral. Since I have been able to study actual specimens, however, I have come to doubt the correctness of this view. On the other hand, the general form should not be entirely ignored. It seems improbable that animals whose structure so resembles that of branchiopods should not have had some sort of ancestral relationship.

As will be noted in the summary of views cited above, all have agreed that Opabinia is an anostracan branchiopod. Hutchinson (1930, pp. 1–13) has recently restudied the specimens, and found that, although the structure was in most respects comparable to that of modern representatives of this order, still there were certain differences, which caused him to erect for it, and a few other extinct species, a new suborder, the Palaeanostraca.

The anostracan characteristics cited by Hutchinson are: absence of carapace, general form and size, presence of pedunculate eyes, position of the antennae and probable reduction of the antennules, a nearly uniform series of foliaceous trunk limbs, and the presence of a frontal process in the male. As may be seen, these are chiefly characteristics of the body, not of the appendages. By his reference to "foliaceous" limbs, Hutchinson apparently did not mean to imply that the limbs were phyllopodan. As figured and described by him, the appendages of the trunk are long, blade-like, smooth externally, with "very strong thick setae" on the inner edge. I am inclined to think that Hutchinson, unaccustomed to dealing with fossils, was misled by the extraordinary state of preservation of the specimens.

Through the kindness of Dr. Resser, I have been able to study Walcott's types (1912, pl. 27, fig. 6, and pl. 28, fig. 1). Both are excellently preserved, but the structure is clearest in the specimen figured by Wolcott on pl. 28 (U.S. Nat. Mus. no. 57,684). This is exposed from the dorsal side with the greater part of the test broken off, so that most of the appendages are revealed. Enough of the shell remains to show that the axial lobe was narrow, and that the pleural lobes were sufficiently wide to cover the appendages when in their natural position. No endopodites are seen, but the exopodites much resemble those of Neolenus. I was unable to see any traces of segmentation in any exopodite, but since the rounded distal end lacks filaments, that part is probably homologous with the outer segment of Neolenus. The anterior margin appears to be thickened, and the posterior edge of the greater part of the shaft supports long, flattened filaments. The adjacent members of this fringe overlap so much as to give the appearance of a continuous plate. This doubtless accounts for Hutchinson's description of the appendage as carrying a series of "very strong thick setae" on the "internal edge." Walcott's figure 1, pl. 28 has been considerably retouched, but gives a fair idea of the filaments of the exopodites. That the filaments are really discrete is clearly shown by a specimen with the green label numbered 40A (U.S. National Museum).

According to this interpretation, the chief non-branchiopodan characteristics are the presence of pleural lobes, a small number of abdominal segments, and the retention of the trilobitan exopodite.

Walcott (1931, p. 15) has given much new information about the appendages of Burgessia, showing that they are typically trilobitan, those of the trunk having both exopodites and endopodites. Both antennules and antennae are simple. Waptia has, according to the most recent restoration (Walcott, 1931, p. 20), endopodites only on the thorax, and exopodites only on the anterior segments of the abdomen, a most extraordinary combination. We probably have much to learn about this creature. In any event, the appendages are trilobitan.

Burgessia and Waptia are decidedly notostracan in habit. Both Fedotov and Henriksen placed Burgessia in or near the Notostraca, but both assigned Waptia to the Malacostraca. If any great weight is given to its trilobite-like appendages, the latter assignment is obviously impossible.

Although, with present knowledge, there are no real connecting links between these Mid-Cambrian "branchiopods" and modern ones, future discoveries may yield them. Such forms as *Lepidocaris rhyniensis* (Scourfield, 1926, pp. 153–187), from even so young a deposit as the Mid-Devonian, will probably fit into the sequence, although rather far along in the series. Scourfield points out that the first three pairs of appendages on the trunk are practically phyllopodan, whereas those on the fourth to eleventh are biramous, similar to those of young copepods. Apparently the condition is what Jackson has characterized as a "localized stage in development." The first three pairs show a modified, the others a primitive condition. The anterior limbs have a well developed corm, with a gnathobase, five endites, a terminal lobe, and an exite or flabellum appearing as a process on the outer side. The remaining trunk appendages are biramous, the endopodite and exopodite each consisting of a single segment, as does the protopodite. The latter shows rudimentary endites, and a well developed gnathobase. As Scourfield points out, there is a clear transition from one type of limb into the other, showing that the phyllopodan limb is a modification of the biramous type.

Students of the Mid-Cambrian fossils will see, in the copepodoid limbs on the 4th to 11th segments, vestiges of a degenerate trilobitan appendage. It is especially interesting to note that the protopodite is unsegmented throughout the series. The corm and endites are obviously modifications of the trilobitan coxopodite. Scourfield homologizes the terminal lobe with the endopodite, and the flabellum with the exopodite. There seems, however, some reason to interpret the series as indicating that the endopodite was lost, hence the exopodite formed the palmate terminal lobe, and the flabellum was a new outgrowth on the outer side of the corm. Whatever the interpretation, Lepidocaris is an extremely important link in the series connecting the Cambrian branchiopod-like animals with the real branchiopods. It is particularly interesting in that it indicates that the phyllopodan type of limb was just beginning to be evolved in Mid-Devonian times, perhaps in response to the invasion of the fresh waters by this type of crustacean.

As a result of this review of the evidence accessible up to the present time, it seems that the best procedure is to remove the Mid-Cambrian forms from the subclass Branchiopoda, although still considering them as belonging to the stock from which the modern group was derived.

The Mid-Cambrian Malacostraca

Turning now to another group, it will be noted that Fedotov doubted the propriety of referring Hymenocaris to the Malacostraca as a member of the Leptostraca. I now believe he was right in this, although Henriksen supported the view of Walcott, which I had previously followed. Here again we are confronted with the question of the relative value of form and appendages. In this case, however, we are dealing with an almost extinct group, the Leptostraca being represented at the present time only by four genera of the family Nebaliidae.

Although great numbers of bivalved crustaceans have been described from Paleozoic strata, very few have been found which show any appendages. The present opinion as to their distribution in various orders is shown by Ulrich and Bassler in their recent monograph on the Cambrian Conchostraca (1931, pp. 4, 5). The small bivalved forms found in the Cambrian are referred to the Conchostraca because the adductor muscle scar of most of them is near the anterior margin, just below the ocular tubercle. The highly problematical Ribeiria, Euchasma, Eopteria, etc., are referred to the Notostraca, as has been the custom for some time. Anomalocaris, Hymenocaris, and Walcott's genera from the Mid-Cambrian are placed in the Hymenocarina, under the Phyllocarida, and recognized as Malacostraca. Other somewhat similar fossils of the Paleozoic are referred to the suborders Ceratiocarina, Discinocarina, and Rhinocarina of Clarke, all supposed to be malacostracans.

Ulrich and Bassler consider the present classification as a tentative and unsatisfactory one. They state: "The correct classification of the small Cambrian bivalved Crustacea is a difficult question. If the superorder Branchiopoda were to include the Phyllocarida as an order or were considered as closely allied, we would not hesitate to place them in the same general association, as we are impressed with the view that these Cambrian forms are an early phase of offshoot of the stock from which the Branchiopoda and Phyllocarida on one hand, and the Ostracoda on the other were derived."

Looking over the illustrations, one is inclined to agree with them that the Ostracoda may well have been derived from the Bradoriidae and Beyrichonidae. In fact, with the exception of *Fordilla troyensis* and *Modioloides prisca,* all the specimens which they have figured lack the growth-lines of the modern Conchostraca. It is true that these shells differ from those of ostracods in the position of the adductor muscles and some other features, but they do not greatly resemble modern conchostracans. Would it not be better to give a new name to this group than to force them into either the Branchiopoda or Ostracoda? The important point is that they are probably ancestral to the latter group. We do not know their appendages, but from our experience with the other Cambrian arthropods we can safely say that they were neither phyllopodan nor ostracodan.

Among the Cambrian crustacea with large compressed carapace, *Hymenocaris perfecta* Walcott is the only real guide, although something is known of the appendages of Anomalocaris. The strongly developed endopodites and exopodites of the anterior part of the trunk of *Hymenocaris perfecta* are distinctly trilobitan, not at all malacostracan. Should the general resemblance of the body to that of Nebalia outweigh the evidence derived from the appendages?

In Clarke's classification (Eastman-Zittel, 1900, p. 653 et seq.), Hymenocaris is given a very isolated position, having been made the type and only member of a suborder of Phyllocarida, the Hymenocarina. If this view is correct, it seems that there is little reason to consider that there is a continuous series connecting it with the Nebaliidae. The basis for the separation from the Ceratiocarina, to which suborder most of the Paleozoic fossils of this general type were assigned, was that the carapace was univalved, without rostrum in the former, and bivalved, with a free rostrum, in the latter. The carapace of the nebalioids is of course univalve.

Several specimens in the Museum of Comparative Zoölogy show that *Hymenocaris perfecta*, although univalve, has a deep, narrow furrow along the middle of the back, which may indicate the beginning of a hinge. Specimens flattened from above show a deep emargination in the anterior outline, and two individuals have a rostrum inserted in this cleft. This indicates that the Mid-Cambrian specimens referred to Hymenocaris are, in form at least, not very widely different from Ceratiocaris.

It is of course possible that the Hymenocaris of the Mid-Cambrian does not, after all, belong to that genus, but that question may be held in abeyance for the present.

The only one of the Paleozoic "bivalved" crustaceans whose appendages are at all well known is Nahecaris (Broili, 1928, pp. 1-18; 1929, pp. 253-63). Some beautifully prepared specimens from the well known Lower Devonian slates of Gemünden and Bundenbach enabled Broili to determine the nature of many of the appendages. The antennules are biramous, a shaft of two long segments bearing a pair of multisegmented tactile organs. The antennae are also biramous, the exopodite composed of numerous ring-like segments, whereas the less flexible endopodite has the proximal half made up of at least two long segments, the distal of short rings. The other cephalic appendages have not yet been seen.

The trunk, according to Broili, consists of eight thoracic and eight abdominal segments. In this count he considers the last apparent segment to be a combination of the last abdominal with the telson. This may very well be the case, as the lateral spines unquestionably are attached to it, and not to the segment ahead of it.

The first eight pairs of appendages are slender, the first the most elongate. These are biramous, the exopodite weaker than the endopodite. The others seem to be uniramous but this is probably a matter of imperfect preservation.

Broili has restored the endopodite as consisting of a single blade, but this likewise is probably due to the imperfect preservation of the specimen. In another individual, which he described in his second paper (1929, p. 262), he detected indications of joints. It seems very probable that the endopodites were segmented.

Five segments of the abdomen bear biramous pleopods, the endopodites and exopodites about equal in strength, each apparently consisting of one setiferous segment.

Broili was impressed by the differences to be noted on comparison of Hymenocaris, Nahecaris, and the Nebaliidae. He saw more similarity between the appendages of Nahecaris and those of Sergestes, a modern pelagic decapod. He concluded that Nehecaris was really malacostracan, but not a phyllocarid, erecting for it the group of Nahecarida, to have the same rank in the classification of the Crustacea as the Phyllocarida.

I have been fortunate enough, through the kindness of Mr. T. H. Withers, to be able to see some of the appendage-bearing specimens in the British Museum. The appendages of the trunk are not absolutely clear, and, as has been said, it is possible that the endopodites are segmented. The restoration of the tactile organs in the paper of 1929 is much better than the earlier one.

In some respects Nahecaris is more like a decapod than like the Nebaliidae. If the endopodites of the thoracic limbs are really unsegmented, it cannot be ancestral to either. If as seems probable, they are segmented, it is more primitive than either, though probably not directly ancestral, since at least two segments lack appendages.

Although considerable modification of the limbs would be necessary to change them so as to conform to the type found in the Nebaliidae, none of these changes is of an improbable nature. Let us look at the chief structural features.

In the first place, the carapace of Nahecaris is not bivalved. An excellent specimen in the Museum of Comparative Zoölogy, flattened from above, shows conclusively that the shell was all in one piece. It cannot even be interpreted as two shells in symphysis. One wonders how many of the so-called bivalved phyllocarids really had any separation along the dorsal side. The assumption that such separation existed is based chiefly on the fact that the shells as found, show, in many cases, a perfect outline of one valve only, with no trace of the other. It is therefore inferred that the two valves separated automatically on the decay of the soft tissues. In many of these cases one valve may be buried beneath its fellow; in others, separation may have taken place because of the weakness of the material along the "hinge." In still other cases, the carapace appears to have been actually in two parts, as in the Rhinocarina. Curiously enough, Hennig (1922, p. 140) placed Nahecaris in the family Rhinocaridae, a group whose chief characteristic is that the valves are articulated by "interlocking at the single point where they come in contact." Broili points out that Nahecaris has five segments behind the carapace (he counts the anterior half of the telson as an abdominal segment), whereas the Rhinocaridae show only three at the most. Hence he makes a new family, the Nahecaridae.

Since the carapace is all in one piece, and the rostrum is a projection from it, not articulated with it, and since there are four segments (if the whole of the last one be considered the telson), behind the carapace, then the general form of Nahecaris corresponds exactly with that of Nebalia.

If we compare the appendages in detail, we find a certain amount of agreement. The antennules of Nebalia have a peduncle of four segments, a flagellum of short segments, and a scale representing the other branch. Only two segments of the peduncle of Nahecaris are known, but the full length may not have been seen. The exopodite is lost from the antenna of Nebalia. The endopodite has a long peduncle as in Nahecaris.

Lacking the other cephalic appendages of Nahecaris, we may turn to the thoracic appendages. Eight pairs of similar limbs are present in both Nahecaris and Nebalia. In the latter both exopodite and endopodite are present. Both are flattened, the exopodite unsegmented, the endopodite only obscurely segmented, not separated from the basipodite. A large epipodite is attached to the outer side of the basipodite. This type of limb closely approximates the phyllopodan, a condition more nearly reached in Nebaliopsis. Paranebalia and Nebaliella, however, show distinctly segmented endopodites (Calman, 1909, pp. 154, 155). If Nahecaris and these latter are properly interpreted, it would not be possible to derive the nebalioid thoracic limb from that of Nahecaris. It is, however, very possible that the appendages of the latter are really segmented, and that the segmentation has been obscured by the preservation or by the process of cleaning. If they were segmented, the segments must have been short, as in Nebaliella.

The pleopods of the two groups are very similar, except that in the Nebaliidae the third and fourth of the four pairs are uniramous.

From the present evidence it appears that both the decapods and the Nebaliidae may have been derived from some Nahecaris-like ancestor, but that more modification has taken place in the latter than in the former line of evolution. Once again the phyllopodan type of limb seems to be a secondary modification. We may, then, look upon the Nebaliidae, not as intermediate in their characteristics between Branchiopoda and Malacostraca, but as specialized descendants of the really primitive group which gave rise to the higher Crustacea.

As Broili has pointed out, Hymenocaris appears to be more specialized than Nahecaris, because it seems to lack appendages on the abdominal segments. I am inclined to believe that further study of *Hymenocaris perfecta* will show that this animal had appendages on all segments of the trunk. A specimen in the Museum of Comparative Zoölogy shows fragments of exopodites pressed against the test of several of the segments behind the carapace, the last trace of them being on the segment in front of the telson. Although the specimen is unsatisfactory, for the fragments are obviously displaced, if affords a suggestion of a primitive condition.

To recapitulate briefly: the form of Hymenocaris seems to be continued in the Ceratiocarina, to which group the Rhinocarina are allied; appendages are practically unknown in either of these groups. Hymenocaris, with its free rostrum, was probably not ancestral to Nahecaris, nor to the modern Nebaliidae.

There is, however, in the Cambrian, a genus which has a carapace somewhat similar to that of Hymenocaris but which has a fixed instead of a free rostrum. This is Tuzoia, Walcott (Resser, 1929), a crustacean with a univalved but much compressed carapace. The body and appendages are, unfortunately, unknown. It seems probable, however, that it belongs to the same group as Hymenocaris, although certainly not to the same family. It may have been some Tuzoia-like animal which was ancestral to Nahecaris. The general form of the carapace, the abdominal segments, and the peculiar telson, are so much alike in the Ceratocarina, Rhinocarina, and Nahecarida as to make it almost certain that they are all of the same lineage.

Lacking any definite knowledge of the appendages of the Ceratiocarina, Rhinocarina, and Discinocarina, it is probably advantageous to group them, as Broili has done, under von Stromer's name Archaeostraca. If so, we must return to Claus's term Leptostraca for the Nebaliidae, adopt Broili's Nahecarida, group Hymenocaris with the other arthropods with trilobitan appendages, and discard Packard's Phyllocarida.

The general result of this entire discussion is to indicate that the Mid-Cambrian crustaceans are related to animals of later date with similar forms, but that the relationships are not by any means so close as some have supposed. As yet no fossils have been found which show the steps in the change from the trilobitan to the typical crustacean limb, hence no one of the Mid-Cambrian creatures should be placed in any order whose definition is based upon characteristics of modern animals. Personally I do not think they should be included in the same subclasses.

The Position of Leanchoilia

As has already been stated, Walcott considered Leanchoilia to be an anostracan branchiopod, Fedotov suggested that it might be an amphipod, whereas Henriksen removed it entirely from the Crustacea, thinking its relationships were with the Merostomata.

My study of the appendages reveals nothing to support Henriksen's position. A spine-like telson is common enough among the Crustacea; at any rate, this single characteristic would not warrant referring the animal to the Arachnida. On the other hand, the "great appendages" of the head have a typically crustacean structure; they, and others of the limbs, are typically biramous. Under the current definition of the class, Leanchoilia must be referred to the Crustacea.

It is equally obvious that the genus can not be included either among the branchiopods or the amphipods. As in the branchiopods, the appendages are serially similar, but the limbs in no way resemble the leaf-like organs of the phyllopodan type. On the contrary they are essentially of the trilobitan type, closely comparable to the exopodites of Neolenus.

Leanchoilia appears to have been a highly specialized animal, not, so far as I can see, very closely related to anything else, living or fossil.

Suggestions for a Classification of Some Paleozoic Crustacea

In 1920 (p. 148) I proposed the name Haplopoda for a subclass of Crustacea, to include those members of the larger group with two pairs of uniramous tactile organs, but with the other appendages of the trilobitan type. It happens, unfortunately, that the same name was already in use for a tribe of the Branchiopoda. It is therefore necessary to replace it, and I now propose the term Homopoda, in allusion to the likeness of the various pairs of limbs.

Since it is thus necessary to change the name of the subclass, it is an opportune time to modify the definition. The limits of the group, as first defined, were too narrow for a subclass, and the wording did not actually express what I had in mind at the time. The following scheme will perhaps serve to express the relationships of the various groups so far as our present knowledge will permit:

Class CRUSTACEA

Subclass TRILOBITA Walch

Subclass HOMOPODA (nomen nov.)

Crustacea with two pairs of tactile organs, the other appendages trilobitan. Biramous appendages on some or all the trunk segments. Carapace present or absent. No facial sutures.

Order MARRELLINA Raymond

Homopoda with trilobite-like form, pleural lobes reduced. Antennae uniramous. All segments behind the antennal bear biramous appendages.

Genus Marrella Walcott

Order PSEUDANOSTRACA nov.

(Leading to Anostraca)

Homopoda without carapace. Appendages on all segments, or absent from one or more of the posterior ones. Not all appendages are biramous.

Family OPABINIDAE Walcott

"Fifteen pedigerous segments followed by a postpedigerous portion divided into two parts, of which at least the anterior one is presumably segmental. Frontal process bifurcated only at the apex." (Hutchinson, 1930, p. 12).

Genus Opabinia Walcott

Family LEANCHOILIIDAE nov.

All segments except the telson appendagiferous. Antennae biramous, specialized.

Genus LEANCHOILIA Walcott

? Genus BIDENTIA Walcott

Family YOHOIIDAE Henriksen

Not well enough known for characterization.

Genus YOHOIA Walcott

Order PSEUDONOTOSTRACA nov.

(Leading to Notostraca)

Homopoda with a depressed carapace. Some of the posterior segments without appendages.

Family BURGESSIDAE Walcott

Carapace large. All segments behind it narrow, without appendages.

Genus BURGESSIA Walcott

Family WAPTIDAE Walcott

Appendages on all but six of the segments behind the carapace. Telson provided with a pair of swimmerets.

Genus WAPTIA Walcott

Family PROTOCARIDAE nov.

Carapace distinctly depressed, bilaterally symmetrical with respect to a median "hinge." Trunk with numerous short segments, the anterior ones appendagiferous.

Genus PROTOCARIS Walcott (emend. Resser)

(See Resser, 1929, p. 12)

Order HYMENOCARINA Clarke (emended)

Homopoda with a compressed carapace. Rostrum free or attached. Biramous appendages on anterior portion of trunk.

Family HYMENOCARIDAE Salter (emended)

Carapace a single shield arched over the anterior part of the body. Rostrum free. Seven to nine segments behind the carapace.

Genus Hymenocaris Salter (emend. Walcott)

The genera Hurdia, Fieldia, and Carnarvonia may belong to this family.

Family ANOMALOCARIDAE nov.

Carapace as in Hymenocaris. Trunk elongate, large, with appendages on all segments except the last.

Genus Anomalocaris Whiteaves

Family TUZOIIDAE nov.

Carapace with a median keel, prolonged into a rostrum. Surface reticulate.

Genus Tuzoia Walcott (emend. Resser).

Order AGLASPINA Walcott (Leading to Xiphosura?)

(See Raymond, 1920, p. 149).

Subclass XENOPODA Raymond. (Leading to Merostomata?)

(See Raymond, 1920, p. 149).

Subclass ARCHAEOSTRACA von Stromer

Crustacea with a compressed or, more rarely, a depressed carapace. Appendages unknown.

Order BRADORINA nov. (Leading to Ostracoda)

Small, ostracod-like crustaceans with muscle scar high on the anterior end.

Families BRADORIIDAE Matthew, BEYRICHONIDAE and INDIANIDAE Ulrich and Bassler. (See Ulrich and Bassler, 1931)

Order CERATOCARINA Clarke

(See Clarke, 1900, 1913)

Order RHINOCARINA Clarke

(See Clarke, 1900, 1913)

Order DISCINOCARINA Clarke

(See Clarke, 1900, 1913)

Archaeostraca *incertae sedis.* Euchasma, Eopteria, Ischyrina, Billings; Technophorus, Miller; Ribeiria, Sharpe; Ribeirella, Shubert and Waagen.

Subclass MALACOSTRACA Latreille

Order NAHECARIDA Broili

Family NAHECARIDAE Broili

Genus NAHECARIS Jaekel

Order LEPTOSTRACA Claus

Family NEBALIIDAE Baird

Subclass Branchiopoda Latreille

Order LIPOSTRACA Scourfield

Carapace absent. Anterior trunk-limbs foliaceous; remainder biramous.

Family LEPIDOCARIDIDAE Scourfield

Genus LEPIDOCARIS Scourfield

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